This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

B 1,069,192

GENERAL LIBRARY

OF

University of Michigan

Presented by

State Geologist

Oct. 2 1902

QE
125
.A5

3rd

REPORT

OF THE

STATE BOARD OF GEOLOGICAL SURVEY

OF MICHIGAN

FOR THE YEAR 1901

BEING THE REPORT OF

ALFRED C. LANE

STATE GEOLOGIST.

BY AUTHORITY.

1902.
WYNKOOP HALLENBECK CRAWFORD CO. LANSING, MICH.
STATE PRINTERS.

BOARD OF GEOLOGICAL SURVEY

1901

EX OFFICIO:

THE GOVERNOR OF THE STATE,

HON. A. T. BLISS, *President.*

THE SUPERINTENDENT OF PUBLIC INSTRUCTION,

HON. DELOS FALL, *Secretary,*

THE PRESIDENT OF THE STATE BOARD OF EDUCATION.

HON. E. F. JOHNSON, - - -	January 1 to April 26
HON. LINCOLN AVERY, - -	April 26 to November 29
HON. PATRICK H. KELLEY, - - -	November 29

ILLUSTRATIONS

Figure 1. Illustrating possible occurrence of gas or oil.
2. Reef in the Alpena Limestone.
3. Worn head of Stromatopora.
4. Contours of base of Antrim Black shale in Cass and Berrien counties.
5. Sketch map of 1823, and 1901 shore lines of Sec. 18, T. 9 N., R. 17 E.
6. Extract from Lake Survey map (1858) of same region.
7. Extract from Lake Survey map of south end of Lake Huron, showing location of the maps of figures 5 and 6.

Plate I. Physiography of Alcona County, by F. Leverett—opposite page 32.
II. Soil map and geological section of Alcona County—opposite page 64.
III. Plant Societies of Kent County, by Burton E. Livingston—opposite page 80.
IV. Contour map of Kent County, by J. F. Nellist—opposite page 96.
V. Pine stumps in dry and wet ground—photographed by C. D. McLouth—opposite p. 104.
VI. Surface geology of Lapeer County, by F. B. Taylor—opposite page 112.
VII. Cross-section north from Alpena, by A. W. Grabau—opposite page 168.
VIII. Index map to outcrops in the region of Little Traverse Bay, by A. W. Grabau—opp. p. 208.
IX. Geological map of Michigan, by A. C. Lane—opposite page 224.
X. Map of Manistee County, by J. L. Sibben—opposite page 236.
XI. View looking south from north line of Haywood estate—opposite page 282.
XII. View north from north line of Haywood estate, showing bedding lines of middle division.
XIII. Caved masses of clay, Sanilac County bluffs, awaiting wave disintegration.
XIV. General view, cliffs and flat country, looking north over Haywood estate.
XV. Algonquin beach and underlying clays exposed in bluff.
Plates XI. to XV. photographed by C. D. Gordon.

TABLE OF CONTENTS

	PAGE
Letter of Transmittal	3
Tuscola County, Saginaw County	5
Bay County	6
Preliminary report on Arenac County, by W. M. Gregory	9
Table of contents of this report	11
Alcona County, by F. Leverett and A. C. Lane	31
Table of contents of this report	33
Alpena County	77
Kent County	79
The Distribution of Plant Societies of Kent County, by Burton Edward Livingston	79
Introduction, A New Field for Research	81
Literature	82
Kent County—Its Climatology	83
Geology of the county	84
Methods	86
The Upland Societies:	
1. The Five Societies Characterized	87
Table of the Upland Plant Societies	88-91
2. Distribution	91
3. Generalizations	92
a. The Soil Factor	92
b. The Historic Factor	95
The Lowland Societies:	
a. The Pond Swamp Group	98
b. The Lake River Group	100
Generalizations on the Lowland Flora	101
Conclusions	102
Muskegon County	104
Some general remarks on the topography, soils, water sources, flora, etc., of Muskegon county, by C. D. McLouth	104
Washtenaw County	107
Lapeer County	108
Surface Geology of Lapeer County—Summary of Report of Progress, by F. B. Taylor	109
Economic Geology	119
The Economic Geology of Michigan in its relation to the business world	121
Raw materials	121
Location	122
Water facilities	123
Interrelation of raw materials	123
Saginaw the center of attraction	124
Union of industries	125
Water power	126
Wealth in wood	127
Oil and gas	128
Iron	128-131
Copper	131
Sandstone	134
Limestone	135
Salt	135
Gold, pearls, diamonds, etc., conclusion	136

PAGE.
Coal and Marl ... 137
Letter by B. Walker on the Marl Fauna ... 137
Limestones ... 139
Stratigraphy of the Traverse Group of Michigan, by A. W. Grabau ... 161
Introductory, previous work ... 163
Descriptions of localities (Thunder Bay and Presque Isle) ... 165
Location and extent of the sections ... 165
Topography of section ... 166
Topography of the shore line ... 168
Stratigraphy of the Eastern Alpena region—A. Well records ... 168
B. Records from outcrops ... 174
Alpena limestones, loc. 1 ... 175
Owen Fox's quarry ... 176
Richard Collins' quarry ... 176
Analyses ... 179–183
Loc. 2, 3, 4—Lower Traverse series—a. Long Lake shales and limestones ... 184
Loc. 6, 7, 26 ... 185
Loc. 27, 28, 8, 32, 33 ... 186
Loc. 33a, 34, 10, 30, 20 ... 187
Loc. 29, 11-13, 31, 31c—Alpena Portland Cement Company clay pits ... 188
Loc. 14 ... 189
Loc. 35, 37, 19, Grand Lake ... 190
B. The Bell shales ... 191
The Dundee limestones ... 191
Thunder Bay series, Traverse upper shales and limestones, loc. 1c, loc. 21 ... 192
Loc. 24, Boom Company's dam ... 193
Loc. 25, Warner brickyard ... 194
Loc. 22, Stony Point ... 195
Loc. 23, Partridge Point ... 195
Little Traverse Bay region ... 197
A. Well records ... 197
B. Records from outcrops ... 198
Thickness of Traverse group of Little Traverse Bay ... 210
Deep wells and prospects for oil and gas ... 211
Southwestern District ... 212
Southeastern District ... 214
Ypsilanti, Ann Arbor, Riga, Blissfield, Milan, Britton.
Port Huron District ... 221
New Baltimore, Saint Clair, Wallaceburg.
Northern part of the State ... 227
Bay De Noc, Asphalt in the Upper Peninsula, Cheboygan, Grayling.
Lake Michigan Shore ... 233
Muskegon, Manistee.
Salt ... 239, 241
Meteorites ... 243
Geothermal Gradient ... 244
Mammoth and Mastodon ... 252
Upper Peninsula ... 254
Relations of the Geological Survey ... 256
College of Mines, Other Societies.
Mineral Statistics ... 260
United States Geological Survey ... 260
Recommendations ... 263
Appendix ... 267
The Port Huron Oil Field by C. H. Gordon ... 269, 275
Geological Relation of the Northern Oil Field ... 272
The Canadian Oil Field ... 272
Test well, Petrolia; Dickens well, Sarnia; Gristmill well, Sarnia; Courtwright's well.
The Port Huron Field ... 275
The Stock wells, Bailey well, Grand Trunk Junction well, Marysville well, Fair well, Wadham's, Beard's well, Abbotsford, Valley Center well, Well's bore hole, Sweitzer well, Shaw well.
Wave cutting on west shore of Lake Huron by C. H. Gordon ... 283
Locality, first survey, resurvey, rate of waste, other historical data.
Illustrations ... 291

THIRD ANNUAL REPORT

OF THE

STATE GEOLOGIST

ALFRED C. LANE

TO THE

BOARD OF GEOLOGICAL SURVEY

FOR THE YEAR 1901.

LETTER OF TRANSMITTAL.

OFFICE OF THE STATE GEOLOGICAL SURVEY,
LANSING, MICHIGAN, Dec. 31, 1901.

To the Honorable the Board of Geological Survey of the State of Michigan:

HON. A. T. BLISS, *President.*
HON. P. H. KELLY.
HON. DELOS FALL, *Secretary.*

Gentlemen—You have deemed it wise for me to make my annual report more full than usual this year,* and include therein reports of progress that shall give the chief results of the work, in regard to a number of scientific and practical matters which cannot be published in more final form for some time. Inasmuch as this involved more work and a start upon the report before the end of the calendar year the details of business and finance are placed at the end, to which they could be added at the last.

The work may be conveniently treated as heretofore by areas and by subjects, the units of area being in general counties. The counties upon which we are at work will be taken up in the order in which they have been taken in hand, but when we expect in the near future to have the report ready, the account of the state of the work will not be so full.

* My two previous annual reports were short, and contained not much matter of scientific interest, so that I did not recommend them to be printed by the State. They will be found, however, practically complete, in the Michigan Miner for February, 1900, and January and February, 1901, the publisher, Mr. C. B. Schaefer, furnishing 500 reprints to the Board.

TUSCOLA COUNTY.

Prof. C. A. Davis, of Alma College, who has been preparing the report upon Tuscola county, has been transferred to the chair of forestry at the State University, a place for which his knowledge of geology and botany, on the relation of which to forestry I elsewhere touch, especially fits him.

The necessary duties involved, and some brief but very fruitful studies on the origin of our marl deposits from a botanist's standpoint, showing the important part which Chara has played therein, have delayed his report. In its surface conditions Tuscola county consists of strips running northeast and southwest. The northwest corner is a fertile and recently emerged lake bottom mainly of clay with superficial sand ridges. Then from the northeast corner between Gagetown and Cass City there is a tongue of rolling till. Then the valley of the Cass is very largely sand and boulders washed from the ice, or deposited by the great stream which once occupied the Cass valley.* Finally in the southeast corner we come upon some deeply cut rough till country once more.

Recent explorations about Vassar, while showing that coal is there, have not found it in quantities enough to warrant mining.

The beet sugar factory at Caro has found a large flow of water in the Napoleon sandstone, as I told the driller he might expect. This sandstone comes next underneath the drift in the southeast part of the county and dips gently to the west. It will generally furnish a good supply of water but poorer qualities of water that sometimes occur above it will have to be cased out.

SAGINAW COUNTY.

The preparation of the report on this county has been in my hands personally. I will not plead pressure of other duties for delay in its appearance though I have not been idle, but the reason why I allowed other matters to interfere have been as follows:

There are no outcrops of bed rock in the county, and therefore the geologist is dependent almost entirely upon information furnished him by exploring companies. Certain of the companies have been very generous in furnishing material, and others have been equally generous in promising material, which, for one reason and another, it has not been

* See Report on Huron and Sanilac counties, Vol. VII.

convenient to give as yet, while in the meantime records have been steadily accumulating. One of the things I am most anxious to do in Saginaw county is to prepare a map of the bed rock surface. This is of importance for coal mining, as the danger of mining into old channels is not inconsiderable.

It seemed wise to wait therefore for this material, so as to make the report on the county fairly complete, rather than to issue one which would be out of date before it could be released from the hands of the printer. But in the meantime I have tried to give publicity to some of the more important economic results. Much of the material regarding the coal of the county will be found in my coal report.*

It will be noticed that I find seven coal seams, three of them at least important enough to work. The two upper or Verne seams are higher in sulphur and volatile matter. The lower or Saginaw is higher in moisture, but very low in ash and sulphur, and there are likely to be lower seams.

In another place in this report under the head of prospects for oil and gas, will be found an account of the upward flexure of the Napoleon sandstone near Saginaw which seems to exist. This sandstone seems to have little if any rise when followed from north-northeast to south-southwest, but probably falls quite rapidly to the west.

The soil of the county is prevailingly clay. In some places patches of clay till are left bare and there are also areas of river silt and of sand, but the latter is not usually very deep. The sand is generally more than eighteen feet above lake level, and a large part of the county is below this.

Another reason for not pushing the publication of the county report, is that I found it would be well to wait until the contours of Bay county were adjusted before preparing the contour map. I have, however, studied carefully the altitude of the East Saginaw datum, and found it to be 582.3 A. T. (supposing that the United State Lake Survey Plane of reference at Milwaukee, known as Highwater of 1838, is 584.38 A. T.), with a probable error of only two or three hundredths of a foot, and no perceptible change in altitude (of two-tenths of a foot, say) in the past forty years. With the help of Mr. Charles Holmes, I have been able to refer all the levels about Saginaw, and the profiles of all railroads mining into it to this datum. This matter is treated of later under elevations.

BAY COUNTY.

The field work of Bay county, which has been mainly in the hands of Mr. W. F. Cooper, is practically complete. In this county, which is also flat, over $10,000 worth of drain levels are said to have been run. Owing to political vicissitudes much of the work is said to have been repeated twice. To get the full benefit of the many miles of accurate levelling it was, however, necessary to run some thirty-five miles of levels to tie the

* Part II of Vol. VIII.

various system levels. For this we employed Mr. J. H. Blomshield, former city engineer, and the Mr. Cooper has been employed much of the time in adjusting these levels.

The soil map of the county is now complete. Mr. F. D. Owens, of the M. A. C., has made some special studies of the waters, and we have also assisted another Agricultural College student, Mr. G. M. Bradford, who is studying botany.

PRELIMINARY REPORT

ON

ARENAC COUNTY

AND PARTS OF

OGEMAW, IOSCO, AND ALCONA COUNTIES

BY W. M. GREGORY.

PRELIMINARY REPORT

ON

ARENAC COUNTY

AND PARTS OF

OGEMAW, IOSCO, AND ALCONA COUNTIES

BY W. M. GREGORY.

county and on the Au Sable river is purely a myth as far as actual specimens produced, and copper in Arenac county is drift material of no significance. The rumors regarding coal are of such a character as deserve careful discussion and will follow in this paper. The true mineral wealth lies in extensive deposits of limestone, gypsum, building stone, brine bearing rocks, marl and clay.

§ 2. *Limestone.*

The limestones of this region are of special interest to those desiring stone for burning, hydraulic cement, road ballast and beet sugar manufacture. The formations outcropping are the Upper Grand Rapids or Maxville limestone, and the Lower Grand Rapids of the Michigan series.

In Arenac county the point of contact of the Maxville limestone and the Lower Grand Rapids group is on the shore of Lake Huron, five hundred feet north of the northeast corner of Sec. 24, T. 20 N., R. 7 E., north of Harmon City. At this point the banks are fifteen to twenty feet high. The entire ledge shows the effect of lake action and the following section is well exposed:

4 feet clay or till.
3 feet red clay, with particles of lime.
1½ feet white clay.
3 inches cherty limestone.
5 inches cherty limestone and sandstone closely interstratified.
1 inch shale and brownish limestone.
8 inches limestone.
6 inches brown sandstone.
4½ feet bluish gray sandstone.
10 inches arenaceous limestone.
5 feet bluish sand, becoming hard in lower layers.

The strata are quite irregular as the thickness of the limestone varies and, as Winchell has noted, the dip from this point seems to be north and south.

Going north one-eighth of a mile on the lake shore from the above outcrop to the old Whittemore test shaft, we find the limestones are blended into brownish sandstones and the layer of bluish gray arenaceous sandstone increases in thickness. At the test shaft we find the first evidence of gypsum, which is directly underneath the lower layer of bluish arenaceous sandstone in a stratum of 1½ feet thickness, which is crumpled and folded with thin seams of argillaceous limestones. From this point north on the shore to Alabaster the lake sand covers all evidences of outcrops. At the above shaft, a 10-foot bed of gypsum was found, but the project was given up, because the inflowing water was troublesome. On the lake shore near the county line of Arenac and Iosco are found numerous sink holes which are very indicative of a good gypsum bed beneath. Off shore from this point in fifteen feet of water are seen white beds of gypsum, being part of the lower bed worked at Alabaster and the one penetrated by wells at Au Gres and Turner.

Returning to Arenac county and following north line of Sec. 24, T. 20 N., R. 7 E., from lake shore one and a quarter mile west to the old quarry of Harmon and Crowell, this exposure is found:

6 to 12 inches of boulder clay.
6 inches arenaceous limestone.
9 feet bright grayish limestone, top of which is filled with flint nodules from 3 to 5 inches in diameter.

It is said that the number of nodules hindered the working of this stone. In 1888, Pollock opened a quarry 160 rods south and west of the first one and the following section is claimed to have been passed:

1 foot clay.
5 feet limestone, suitable for burning.
1 foot sandstone.
6 feet limestone, brittle and used for building purposes.

The hard flint nodules were absent from this quarry and some very fair building stone has been secured here.

Harmon and Crowell also opened a quarry in the southeast corner of Sec. 24, on the lake shore, here one and one-half feet of good limestone was secured, covered with greenish black shale. This is the White Stone Point limestone, covered with the shale which outcrops at Harmon City.

The limestone ridges in which the above quarries were opened, commence near the northeast corner of Sec. 13, T. 20 N., R. 7 E., and extend southwest into southeast corner of Sec. 14, and then southerly to the center of Sec. 23. Here the ridges are broken, for they do not appear again until we reach the north line of Sec. 26, where a few acres are exposed, and in Sec. 27 the same is again exposed in the southwest part of Sec. 27 at the house of W. M. Davis.

At White Stone Point an exposure of brittle grayish limestone occurs, which is in 6 inches of water and extends out into the lake for over 200 feet at a depth of not over four feet. A careful examination of this region, especially southwest of Harmon City, might reveal a ledge of fair thickness and quality suitable for hydraulic cement, building purposes or lime burning.

At Point Au Gres low calcareous ledges of an arenaceous limestone occur nearly half a mile in width along the water's edge. Nowhere is the outcrop over 8 feet above the lake. Here are exposed 5½ feet of arenaceous limestone with streaks of brownish sandstone. Calcareous concretions are found which closely resemble those found in the Griffin quarry at Omer. The lower bed is a brittle light gray limestone, containing some few flint nodules and mussel-like shells. Much stone has been removed from this place for building purposes, but none used for burning lime, as it is considered too sandy.

The above outcrop apparently goes to the northwest, for indications of its presence are found near the center of Sec. 36, and also on the west line of the same section. In the northeast corner of Sec. 27 a well-defined exposure occurs west of the schoolhouse. The beds are flat, only the top layers being exposed. The course is to the northwest from this place. The top bed is five inches of grayish brittle limestone, then a brownish sandstone, of three to four feet thickness, then seven feet of a dark grayish limestone. These sections are made from a well which passes into the rock at William Mackin's house west of the school.

Following to the northwest we find a large outcrop of eighty acres

extent east of the center of Sec. 17, T. 19 N., R. 6 E. Mr. Omsted of Au Gres opened a small quarry in southwest corner of this section a number of years ago, and used the stone for the foundation of Mr. Grimore's house at Au Gres. It is believed that this stone is too arenaceous for burning. Mr. Omsted tried burning, but found that the lime was not suitable for use.

If the outcrop is traced still farther to the northwest, in Sec. 1, T. 19 N., R. 5 E., an excellent exposure exists. Starting east of the center of this section and running to the northwest corner, the limestone forms a distinct ridge of 25 feet height and one-eighth of a mile in width. At the east end of the ridge, Mr. Thomas Burt has had a small quarry opened for several years, and is burning a very satisfactory lime for general purposes. On the top of a six-inch layer of argillaceous sandstone are large angular blocks of limestone which are used for burning, and underneath the sandstone is a good limestone, which has been but little used. Near the west end of this ridge is Griffin's quarry, where material has been taken out for road ballast. The following section will represent the average formation of this quarry:

½ foot clay.
4 feet limestone of varying quality.
Many nodules, containing calcite.
Irregular pipe-shaped lime segregations.
2 feet argillaceous sandstone with many ripple marks.
1 foot brownish sandstone.
2 feet calcareous sandstone.

The lower beds are limestone, as has been shown by core drilling.

The following analyses of the Omer limestone have been made by Dow Chemical Company:

	Sample 1.	Sample 2.	Sample 3.
SiO_2	8.86	0.92	24.67
$(FeAl)_2O_3$	.94	0.43	.80
$CaCO_3$		96.74	.....
$MgCO_3$		1.05	.....

This ridge of limestone ends in Sec. 11, east of the Detroit & Mackinac railroad, on Mr. Parker's farm. Lime has been burned here for several years, and it is of an excellent quality. The limestone used seems to be from the lower beds of the Griffin quarry, which is east one-eighth mile and is 15 feet higher.

Continuing in a northwest direction to the center of Sec. 35, T. 20 N., R. 5 E, here limestone occurs in a larger raised area of 150 acres extent, with but few feet stripping in places. Only the upper beds are exposed and in many places large angular blocks of limestone occur. The quality of this stone for burning will compare favorably with that found in Burt's quarry. On several of the older buildings at Omer this material was used and is still in good condition.

There are rumors of outcrops in the region of Sec. 30, T. 20 N., R. 5 E. This is not improbable for one-half mile west rock is within 15 feet of surface. East of Arenac postoffice a field shows indications of a small extent of limestone near the surface. Mr. Stewart has made several small test pits and found the stone, but the wells of the near vicinity fail to show the stone to be of any considerable extent. A typical specimen from Arenac was analyzed with the following results:

$CaCO_3$	94.8
Magnesia	1.1
Iron and aluminum	.9
Insoluble	1.7
Organic Matter by difference	1.5
	100.00

In Iosco county in Sec. 30, Burleigh township, at the old Keystone dam is an extensive outcrop of Maxville limestone. The following strata are exposed:

2 feet gray, brittle, hydraulic limestone, bottom layer filled with flint concretions.
3 feet arenaceous limestone, with lime concretions of irregular shape.
1 foot brittle, whitish limestone, with brownish streaks.
4 feet grayish free stone.

The upper layer has been analyzed with the following results:

SiO_2	6.32
Fe_2O_3, Al_2O_3	3.19
$CaCO_3$	89.10
MgO	.71
H_2SO_4	.00
Loss on ignition	36.06

This would be quite suitable for general lime burning. Its low per cent of iron and magnesia would make it suitable for hydraulic cement in connection with some suitable clay.

The contact of the Maxville limestone and the Lower Grand Rapids is clearly shown at the junction of the Cranner creek and Johnson creek in Sec. 30, of Burleigh township.

The limestone found at the old Keystone dam extends across Sec. 29 at some 15 to 20 feet underneath the drift. Rumors of exposure in Sec. 27 and Sec. 34 have not been verified, but do not seem improbable. In this township, in section one, one-quarter mile north of Detroit & Mackinac railroad bridge, across the Au Gres river on the west bank, is a small outcrop of the brittle light-colored limestone, of six inches thickness, and underneath is 10 feet of bluish and brownish clay shales.

§ 3. *Gypsum.*

The northern part of Arenac, the adjoining territory of Iosco and the southeast part of Ogemaw furnish some excellent outcrops of gypsum. This is because the drift is not thick over the underlying

rocks and then this region is the natural outcrop of the Grand Rapids group.

The most extensive exposures of the Lower Grand Rapids beds are at Alabaster in Iosco county. The beds comprise an available working area of over 480 acres and have an average thickness of 23 feet. In reality, two beds are present, as where this was worked in earlier years a layer of hard fossiliferous limestone and a small stratum of shale were between the two beds, but on working into the deposit the shale and limestone have entirely disappeared. The stripping is stiff boulder clay of 10 to 12 feet in depth. The face of the exposure has been opened for more than a quarter of a mile in length. The beds dip slightly to the southwest and the surface shows the small ravines due to solvent action of water. At the Alabaster quarry a large force of men are employed in quarrying, grinding and calcining.

The impure gypsum, which is mixed with clay and colored with iron, is sold for land plaster. The variety which is streaked like castile soap, with irregular seams of clay, is shipped to eastern markets, where it is made into Mexican onyx. The purest gypsum is ground, heated and converted into familiar plaster of paris. The larger part of the staff material used for the World's Fair building and at the Pan-American came from this quarry.

A 90-foot shaft was sunk several years ago by the Alabaster Company to determine the condition of the lower beds of their deposit. The underlying rock of the quarry is a bluish gray sandstone alternating with hard cherty limestone seams. At different depths several small beds of gypsum occur, the largest one nearly five feet thick, and at 85 feet depth.

At 90 feet a strong flow of water occurred, which stopped further work, and it is quite probable that this represents the bottom of the Grand Rapids group.

In Sec. 28, T. 22 N., R. 6 E., one-eighth of a mile north of the old Glendon dam on the east bank of the Au Gres river is a cut which exposes the following section:

One foot clay; four and a half feet gypsum, top layers very pink; three inches roughly foliated limestone and sandy limestone interstratified; two feet yellow shale; three feet bluish grayish arenaceous shale.

From the sink holes in the vicinity, and the fact that gypsum occurs on ridges, a careful test of this place with a drill might reveal a greater thickness than is shown in the cut.

On the Au Gres river, in Sec. 27, T. 22 N., R. 5 E., the river bottom in the southeast corner of the section is covered with a bluish gray arenaceous shale, which is so closely associated with the gypsum deposits of this region. Northwest, a quarter of a mile from the southeast corner of this section, a three-foot bed of gypsum occurs in bank of the Au Gres river. This is covered by two feet of sandy limestone and underlain by the blackish shales.

Following the Au Gres river through the sections of the southeastern part of the above township many small beds of arenaceous shales are found. A number of sink holes in section 36, outcrops in sections 24 and 12, are reported but have not been found.

At Whittemore, in Sec. 10 of 21 N., R. 5 E., is a well which penetrated several beds of gypsum at 50 feet and 170 feet. North of Whittemore,

at Mr. Armstrong's house, beds of gypsum of five and seven feet thickness were passed at 90 feet and 130 feet in drilling for a flowing well.

In this same township, in section 20, southwest of Whittemore, on Cranner's creek west of its junction with Johnson creek, is a deposit of light rose-colored gypsum in the bottom of the creek. The masses are here exposed for 200 feet along the creek bottom and are covered by a bluish grayish shale with streaks of arenaceous limestone. Careful exploration of the high clay bluffs of this region might reveal a bed of sufficient quality and quantity for working.

Where the Detroit and Mackinac railroad crosses the east side of section 36 of this township, a large floater of gypsum occurs on the west side of the track. This did at one time show in the railroad cut, three feet from the surface. Some prospecting to the northeast might reveal the ledge from which this rock was brought by glacial action. A large sink hole occurs at this point and a small creek empties into the cavity. A drill test in this place might prove that the gypsum was from the underlying rock.

At Turner, in Arenac county, in digging surface wells large boulders of gypsum are found. In digging shallow wells of 25 feet depth it is not uncommon to take out of the solid clay nearly one-half of a ton of gypsum boulders. The water of a flowing well at the schoolhouse in Sec. 8, T. 20 N., R. 6 E., which is east of Turner, gives a strong test for gypsum. Near the corner of section nine, of the same town, Mr. Clukey drilled a 235-foot well and passed eight feet of gypsum at 95 feet. In Turner, near the Detroit and Mackinac depot, is a well of 300 feet depth and a very strong flow. The record of the well shows gypsum of five feet thickness at 64 feet. Mr. M. H. Eymer of this place has a well of 105 feet depth, and at 50 feet passed a 12-foot vein of gypsum.

Several years ago, Albert Hann opened a 36-foot pit east of Turner in southeast corner of section eight. The following section was passed:

25 feet clay.
3 feet bluish grayish arenaceous shale.
1½ feet gypsum.
5 feet hard, flinty limestone, with small seam of gypsum.

Mr. Hann did not continue the work because at this depth a large flow of water occurred and hindered further work.

At Twining, in drilling the flowing well of William Lilleberger, a vein of gypsum was found at 25 feet, but its thickness has not been carefully observed. In Mr. Barr's well, on section 25, which is south one and one-half miles, a 10-foot vein of this same rock was encountered at 20 feet, and the water of several wells in the near vicinity is very bitter, giving with Ba Cl, solution a strong precipitate of Ba SO_4, which is a proof of the presence of gypsum in the water. Mr. Barr states that the mineral comes to the surface 40 rods west of his house, but this outcrop has not been found. There is no question but what a bed of gypsum of fair thickness underlies the region of Twining, Turner and Turtle. Its value for mining can be determined by careful work with a drill.

In Au Gres, Mr. Bradley has a well through 10 feet of gypsum at 50

feet depth. On Mr. Grimore's farm, one and one-half miles north of Au Gres, the rock is found at 40 feet.

The outcrops of this formation have a limited area in this region and no evidence of gypsum of the Grand Rapids group outcropping have been found north of a line connecting Tawas City and West Branch and south of a line between West Branch and Au Gres. Gypsum is found in the deep wells of the Saginaw valley, but the above statement refers to a region in which a search might reveal the rock in suitable condition for practical working.

Judge Sharpe of West Branch is the authority for the statement that three and one-half miles east of West Branch on the Rifle river is an outcrop of gypsum, which several years ago caused much excitement from its size and purity. No careful exploration of this bed has been made and at present it is undeveloped.

§ 4. *Coal.*

Rumors of coal are very frequent from Arenac and occasionally from Ogemaw and Iosco. At present it is not doubted that these counties lie on the border of the Michigan Coal Measures and the Michigan Series. The location of the bottom of the coal measures is a matter of commercial importance to these counties. The field has been carefully examined and these conclusions will aid those who desire to save expensive experiments in testing for coal. From Dr. Lane's examination of the coal in the Bay City and Saginaw region he has found that the coal lies in a large basin, in which the lower veins are less extensive than the upper seams nearer the surface. At the edge of the basin we would not find the deeper beds at all, for they extend only a short distance out from the basin's center. It is obvious that deep drilling at the rim would fail to reveal the lower beds of coal and would penetrate the Michigan series and Marshall sandstone.

The first reports of coal in this State came from the southern rim of the basin at Jackson and the northern edge at the Rifle river. Mr. Bennett, a Pennsylvania coal miner, was first to explore along the river. Bennett and Kinney prospected in 1875 and sold their claims to a Bay City company. This company sunk a test shaft, known as Bennett's shaft, in T. 19, R. 4 E., Sec. 3, N. W. ¼ of N. E. ¼ on the south side of the Rifle river.

In this shaft, according to reports, black shale and coal occurred at 18 feet. This is apt to be correct as far as the shales are concerned, for the shaft was located on a clay terrace 15 feet above river bed, which contains an outcrop of bituminous shale. The entire depth of this shaft was 27 to 29 feet. The upper 14 feet was a loose drift, then three feet of hard calcareous rock, then three feet of hard black slate, and lower seven feet all "cannel coal," which of course is incorrect, as shown by the way the coal burns. At 28 feet this shaft was drifted north 20 rods under the river and a large quantity of the hard black shale removed.

Many attempts were made to ship this coal, several car lots were drawn to Sterling and given a trial on the Michigan Central. It was found to have too much ash and smoke. A large raft was loaded with intention of shipping to Omer, but the project was hindered by the rapids in the river.

The coal taken from this shaft seemed to be of two kinds, one quite bituminous and breaking into blocks, the other a shaly coal of lighter color and more ash. After experimenting some time the company allowed work on the shaft to cease until McLean, of Bay City, in 1879 pumped out the standing water and after a careful examination sunk a shaft 60 rods to the southwest of Bennett's shaft on a high terrace south of river. After passing through 60 feet of sand the venture was given up and no coal was found. No work was done on the shafts until Mr. Sovereign, of Bay City, pumped the water from Bennett's shaft in the fall of 1899 and made a drilling in the bottom. Borings have been made on the north side of the river opposite Bennett's shaft and gave 25 feet of drift and 20 feet of sandstone, with no signs of coal. Mr. Ortman, of East Saginaw, made a boring on the north side in this same location and found 21 feet of drift, then sand rocks, blue shale and black shale to 190 feet, but no signs of coal.* In the southwest corner of Sec. 2, T. 19 N., R. 4 E., which is three-fourths mile southeast of Bennett's shaft, a test was made, rocks, sand and shales were found under 60 feet of drift material at 100 feet, and no positive signs of coal. Mr. James Ramsdell, of Bay City, tested in Sec. 10, T. 19 N., R. 4 E., and found:

75 feet sand.
10 feet clay.
7 sand rock.

And from this point to 200 feet—, shales, fire clay, and at last the underlying limestone. It may be that the shales found will prove small beds of coal, but no extensive beds are shown by the actual tests.

Mr. Stevens, of Omer, dug in river bottom, 14 feet through shales and slate to fire clay, and made a small shaft into the river bank some 25 feet in length. From these indications he sunk a test shaft on the south bank of the Rifle river in Sec. 8, T. 19 N., R. 5 E. This shaft shows the following strata:

12 feet clay.
12 feet shale.
6 feet fire clay.
5 feet shale, very hard.
1 foot coal (Cannel).
1 foot fire clay.
10 feet soft shale.
1 foot coal.

48

The lower coal is block coal and is an excellent quality of steam coal.† Coal of the upper seam contains much sulphur and other mineral constituents and could not correctly be called cannel coal, as only very small seams of the highly bituminous coal occurs in the foot vein. The upper seam dips to lower seam, which is apparently horizontal; if the two meet a fair amount of coal would result. Mr. Sovereign pumped water from

* Michigan Geological Survey, Vol. III, page 142.
† See Analyses in Vol. VIII, Part II.

this shaft in spring of 1900, and an expert miner of Bay City made an examination. The coal of upper shaft was pronounced good; it was not possible to examine the lower vein. Mr. Stevens drilled in bottom of shaft 122 feet and passed the slate and stopped in hard shales, which is no doubt the limestone of the lower formations. A test drill hole was made 25 rods south of this shaft and no coal reported. Mr. Stevens' shaft is located south of Rifle river in N. W. ¼ of N. W. ¼ of Sec. 8, T. 18 N., R. 5 E., and the coal found here is evidently a pockety formation.

At Deep River in 1875 Mr. Stevens, of Bay City, made a 120-foot test hole, and found such fair indications that he sank a 106-foot shaft, which gave:

20 feet drift.
10 feet clay.
53 feet sandstone.
20 feet shale.
1 foot coal.
2 feet shale.

106

The abundance of water which flowed into the shaft from the top of the sandstone is said to have made the project a failure. The wells one mile east of Deep River station reach the sandstone at 10 feet to 20 feet, and the bed of Deep river two miles east is a white friable sandstone, full of small pieces of coal, and in places showing thin seams of black shale. To the northwest of Deep River station in Sec. 29 rock is reached at 75 feet, and in a test hole near the center of this section a small vein of black shale was reached. At Sterling it is 85 feet on the average to rock through the clay. At Culver, on the Michigan Central, Mr. John Dunn tried to secure a good supply of water for a mill and stock by deep drilling, but was unsuccessful. It was 300 feet to dark bluish shale, and going 200 feet into the shale gave no water. In Ogemaw county, T. 12 N., R. 1 E., three tests have been made, and in each case sections show plainly that the regions is well out of the coal basin. To try costly exploration for coal north of range 21 north would be a needless expenditure of time and waste of money. Dr. Lane suggests as the place for commencing preliminary explorations for coal 10 to 15 miles from the limits of the basin. This would make the region of Standish and Saganing quite likely to yield results.

At Omer a rich black bituminous shale is found in many of the drift wells. Mr. Sanderson's well west of the village is a fair example of this class of wells; shale was found in small seams on top of white sandstone. In excavating for the abutments of the Detroit & Mackinac railroad one-eighth of a mile below Omer some two feet of rich bituminous shale was found directly above the sandstone which covers the river bottom for some distance below Omer. No practical use can be made of shale without a roof. Mr. Gore drilled on the east bank of the Rifle river below the bridge at Omer and passed sandrock, shale and limestone. The flowing well near the postoffice in this town passes some 40 feet of shale down 50 feet. Mr. Menzer, in the southern part of town, reached a twenty foot vein of shale at 60 feet. None of the deep wells north of Omer reveal any positive sign of coal, although in some of the deeper

wells at Tawas, Whittemore and Hale a shale is passed which belongs to the Michigan series, and has no relation to coal measures, and has led many to a strong belief in a rich deposit of coal. The strong ridge of limestone from Point Au Gres to the northwest (as described on pages 13 to 15) marks the northern rim of the coal fields.

§ 5. *Water Supply.*

At the present time one of the problems which confronts the manufacturers of this region is fuel for steam production. This was a question of no consideration in the days of abundant pine refuse from the mills, but today a supply of fuel will give a new lease of life to many of the small towns which were established during the period of a large lumbering business.

The development of coal mines has given encouragement to the manufacturing interests of Saginaw and Bay City. The regions north of the coal fields will eventually have to utilize the abundance of water power to be derived from the many creeks, lakes and streams of this region. At the present time long distance transmission of power has been so perfected that it is not impossible to utilize the power of all the rivers of a county.

The Rifle river is especially suited for furnishing abundant water power. For miles this river flows between high clay bluffs, which would render damming easy, and only a small area of land would be lost by flooding. In Ogemaw county, T. 21 N., R. 3 E., Sec. 9, the Rifle river flows over sandstone ledges for more than a mile. The remains of an old lumber dam exist one-eighth of a mile north of the iron bridge which is near the southeast corner of the above section. A head of 10 feet could easily be secured here, and with careful construction, for the river bed is sandstone and the banks solid clay, it would be possible to increase the head to at least 15 feet with an abundant supply of water.

Going down the river from this point to Isle Rapids, one-quarter of a mile west of the southeast corner of Sec. 28 of the above town, the fall is (771-720)* about 50 feet. In Sec. 28 occurs rapids three-quarters of a mile in length over beds of arenaceous limestone. The place would afford a head of at least 10 feet.

Where the abandoned line of the Detroit & Mackinac railroad crosses the Rifle river in Sec. 12, T. 20 N., R. 3 E., the elevation is 693* feet, making a fall of 27 feet from Isle Rapids. Wells creek flowing into the Rifle river in section 19 of the above township, brings in a constant volume of water. The river below the creek's mouth is 100 feet wide, averages three feet deep, and has a current of four miles per hour. Clay banks 40 feet high would afford solid anchor for dam. From the old railroad crossing down river to the mouth of this creek there is a fall of eight feet (693-685).

In T. 19 N., R. 4 E., east part of section three, a dam was built by a lumber company for flooding river. This is 250 feet long, solid clay banks with bed rock forming the foundations. A fall of 15 feet occurs and is the average for the year. Much trouble has resulted from spring freshets. The top of the dam has an elevation of 681 feet A. T., bottom 666 A. T. and a fall of 22 feet from the mouth of Wells creek. Rapids occur in river bed in many places below the dam. In the northeast

* Above tide line (A. T.); Lake Huron is 580 feet above it.

corner of section one, near the town line, is a favorable site which would furnish abundant power for a small flour mill which could draw on the region around Melita for flour, feed and custom work.

At Omer a saw and flour mill are operated by water power. A strong steady head of 13 feet is maintained for the year. The elevation of top of dam is 608 and the bottom is 595. The bottom of river is soft sandstone and shale. The old Rifle river canal in the west half of Secs. 36 and 25 of T. 19 N., R. 5 E., which extends from the river to Wigwam bay has a fall of 15 feet in one and a half miles. Mr. Chesbrough, a prominent lumberman of early days, cut the canal for log driving, and it was unsuccessful on account of the large amount of sand encountered.

Some of the larger creeks flowing into the Rifle river could be utilized for small power. Wells creek at Alger would afford sufficient supply for an overshot wheel for a small mill. Silver creek and Manfield's creek would yield power on small scale.

The west branch of the Rifle river could be relied upon for at least two dams of ten foot head and 75 to 100 feet in width. The east branch of the Rifle river near the north line of T. 22 N., R. 3 E., would provide power for several small mills.

Lake Ogemaw, a glacial lake which is two and a half miles northwest of West Branch and is 175 feet above the town, might at some future time furnish the place with a source of pure water supply and some power. In the basin of the Rifle river a large number of these glacial lakes are found with great variation in elevation. Power could be obtained in many cases by cutting canals.

The Au Sable river, in Crawford, Oscoda, Alcona and Iosco counties, from a short preliminary examination reveals an abundance of power. In the rapids in T. 24 N., R. 7 E., a fall of over 50 feet occurs in four miles. Several very advantageous sites for dams occur in the above township, and it is believed that places would yield 2000 horse power. The extent of the drainage basin, the number of tributaries, the constant volume and the average velocity with the high terraced clay bluff form a stream which will repay careful investigation by those interested in cheap power.

The Pine river, in Arenac county, while a small stream, of which not over 10 miles could be used for power purposes, has a fall of 44 feet between Standish and Saginaw bay. A point near the southeast corner of Sec. 5, T. 18 N., R. 5 E., where the Pine river receives its south branch, would supply power for a small industry, as a creamery. The water supply might fail during a part of the summer. At Deep River, on the Michigan Central, the north branch of the Pine river runs in a narrow valley, which affords an excellent location for a small dam with a head of at least eight feet. On the Pine river at Standish, Mr. Norn has a dam used for a log boom, and this has a head of eight feet, which could be increased enough to supply power for a small mill.

The Saganing creek, in the southern part of Arenac county, is rather deficient in volume to expect much power, although a dam northeast of Worth where the stream begins to pass out of the old lake shore would furnish several farmers with power for a small feed mill.

Tawas river, in Iosco county, with its source in a small group of glacial lakes near the southwest corner of Sec. 31, T. 23 N., R. 7 E., passes eastward through the township between high clay banks capped with sand

at the southeast corner of Sec. 24. At this point it has an elevation of 666 feet A. T., or about 84 feet fall to Lake Huron level. Mr. Rodman has a water power saw mill in section 24 with a head of 15 feet and has an abundance of water the entire year. At Tawas City the river has a fall of three and a half feet in three-fourths of a mile, and a breast wheel at a narrow point would furnish power sufficient for small machinery.

In the northwestern part of T. 23, R. 5 E., lies a small group of glacial lakes very irregular in outline and each having a different elevation. The largest member of this group is Big Long lake, nearly two miles long and a quarter of a mile in width on the average. It is over 35 feet higher than Little Loon lake which is south a quarter of a mile. A connected channel would furnish power for a small feed and flour mill which the country needs.

The Au Gres river, of Arenac, Iosco and partly in Ogemaw, is fed by a large number of small tributaries and a few glacial lakes. The river rises in Styles lake; three-fourths of a mile southeast a dam on the outlet has a head of eight feet, and could be easily increased. At the junction of Hope creek and Au Gres river in Sec. 28, T. 22 N., R. 5 E., an average depth of one and a half feet of water and 20 feet width occurs. The banks are high and of solid clay. Much land would be flooded by a dam which would have a head of 10 feet. The river has an elevation of 655 feet at the Detroit & Mackinac railroad bridge, two miles east of Whittemore. In Sec. 18, T. 21 N., R. 5 E., a lumber dam was constructed and the location is an excellent one for a small mill requiring a 10-foot head. The river between the crossing of the railroad above and the main line north of Turner has a fall of nearly 30 feet (655-620). It would not be possible to utilize the lower course of the Au Gres river for power to any extent, for the low banks would allow too large a tract of land to become waste and swamp. At the junction of Whitney creek and Johnson creek, in Sec. 20, T. 21 N., R. 5 E., a head of 15 feet and a width of 100 feet could be obtained, but summer would lessen if not destroy the power for two months.

Near the center of Sec. 28, T. 22 N., R. 6 E., on the east branch of the Au Gres, the high banks and bed rock of the stream furnished a good lumber dam for flooding the river. The average width is 30 feet and depth one and a half feet, which could be made to give a head of 15 feet. Between this point and the crossing of Detroit & Mackinac railroad at East Branch station there is a fall of 31 feet (671-640); this would supply power part of the year at East Branch. Below this point the river banks are too low to ever allow much use of power.

The value of the water supply of this region lies not only in the abundance of power but also in the large number of flowing wells which may be obtained in many places by careful drilling. An abundant supply of pure water is essential for domestic purposes and is valuable in dairying, cooking and drinking.

The underlying rock formations in this district dip to the south and southwest. Some of the rock strata are more porous than others, which fact enables them to become the source of underground water. The impervious beds above and below a porous stratum hold the water to the level of the lowest outlet and when the beds are penetrated in drilling, if the head is higher than the well a flow results. Then again flows are

formed by drilling through sand, gravel and clay on the slope of a moraine; the sand and gravel acting as the reservoir for the water. Wells of the last mode of formation are quite common near Tawas City and West Branch. Flows from the bed rock occur at Au Gres, Omer and Standish.

At Au Gres, Mr. Badour has a well which gives a strong flow; with traces of sodium chloride, calcium sulphate and some H_2S. The depth of the well is unknown, but it is probably nearly 200 feet, and is near the bottom of the Michigan series. At one time a large bath house and hotel was supplied with the water. At present it is flowing freely and ought to be checked, because water having a strong flow will in time destroy or lessen its head. Flowing wells are easily obtained in the Au Gres country, and some of the enterprising farmers are taking advantage of the quality and quantity of water for dairy and stock purposes. The water is well suited for cooking and cooling purposes, having on an average a temperature of 50 degrees. Small flows are obtained at 150 and 175 feet. These yield a higher percentage of salts and the quantity of water is much less.

At Omer a well of 315 feet depth serves the purpose of the town pump. It gives an abundant supply of water and did supply two small hotels. This well is into rock, and it is quite probable that it reaches the Marshall. The shallow wells of 35 to 50 feet are in the white sandstones and black shales which furnish poor water in small quantity. Mr. Squires had a well near his store which contained so much H_2S and sulphates that it was abandoned.

At Standish the public schools and court house are supplied with wells which vary in depth from 50 to 230 feet. At present time only one well at the primary school building is flowing, although when these wells were seen all were flowing with a strong head. The deeper wells having no flow now had the stronger in 1899. The Wooden Ware Company has a 75 foot well which flows and gives water of the following composition:

$CaCO_3$=2.52 grains per U. S. gallon,	0.043 parts per thousand.
$MgCO_3$=1.74	0.030
$CaSO_4$=2.52	0.043
Na_2CO_3=3.04	0.052

Mr. Norn, of Standish, owns a 1900-foot well drilled by Mr. Coryell, of Bay City. The flow at present is very strong from a depth of 400 feet. Abundant brine was found at 1000 feet to 1300* feet but was easily exhausted. This well seems to have passed into the Coldwater shales, as at 1900 feet the bluish shales were found, but this is only driller's record. Dr. Grigg, of Standish, believes this to be a good mineral water and has a number of cases on record which compare favorably with effects of some of the standard mineral waters.

At Turner and Twining flows are obtained at 90 to 105 feet. At the latter place Mr. Lilleberg has a flow at 90 feet which is medium soft water having a trace of sulphates and carbonates. South of Twining many of the farmers cannot obtain good water for domestic purposes; it is bitter and has an abundance of calcium sulphate which renders it unfit for cooking purposes. Mr. Eymer, of Turner, has a flow at 105 feet which is very hard water, coming from a sandstone layer in the lower Grand Rapids group.

*Salt Inspector S. S. Garrigues reports in 1880, that a 98 per cent brine was met at 1700 feet.

The large flowing well near the station in Turner serves the town for fire protection and is the strongest flow yet described. This well has a total depth of 250 to 280 feet. The water contains more sodium chloride than the shallow well and is similar in density and composition to deep well water of Omer and Au Gres. The well if not allowed to waste itself will furnish abundant water for years. At the schoolhouse in this town a flow is found at 130 feet, and is stronger in calcium sulphate and has a greater density than the deeper well.

At Tawas City at least twenty flowing wells occur from 60 to 125 feet for the shallow flows and two deep wells at 700 feet and 800 feet. The shallow wells are on the "lake side of a water laid moraine" and do not reach rock. A gravel bed is the source of supply and the wells vary greatly in the quality of water, those at 90 feet being very soft, those at 50 to 75 feet showing much calcium sulphate and calcium carbonate. The rock is reached at 95 feet, and wells into the rock give hard water. The wells at the public school and the German school are very strong flows. The latter is the deeper and softer, the former is hard. At ten places within this village are strong flowing wells, and the majority of the flows are allowed to run with no check. Such a valuable water supply ought to be carefully protected from exhaustion and not allowed to run when unused. A more careful report of this region is to follow. This area of flowing wells extends south and north of Tawas City, and only a small distance east and west. At East Tawas the wells are very difficult to obtain and only a very few weak flows have been found by drilling shallow wells. The deeper wells of Tawas City were originally bored for salt, and at the present time these have strong flows on the sites of former extensive saw mills and salt blocks. Where the Gaus hoop mill stood south of Tawas City the well is very strong in chlorides, sulphides and hydrogen sulphide. A similar well occurs a short distance west of Mr. Peter Evertz's store. The percentage of hydrogen sulphide is so high in this well that the characteristic odor is clearly recognized by those in the near vicinity. A combination of waters taken from different depths in this region might make a mineral water of commercial value and lead to the establishment of a sanitarium.

At West Branch a large number of flows exist at 60 to 80 feet for shallow flows and 200 to 240 feet for stronger flows. The deeper are in the bed rock and are very constant in volume, while those of the lesser depths are in gravel beds and quite irregular in quantity.

The value of this cheap method of water supply will undoubtedly lead many people to try for flows. Some regions are suggested in a brief way which might be made to yield a flow. In the vicinity of Glennie, Curtis and West Greenbush, of Alcona county; east of Prescott and south of Sage Lake, in Ogemaw county; in Arenac county west of Standish some four miles, and a four mile strip of country along Saginaw bay from Alabaster to Pinconning is more than likely to yield good flow.

§ 6. *Clay and Shales.*

The rapid increase of the hydraulic cement industry due to the abundance of marl, limestone and coal is creating a demand for clays, low in lime, magnesia and iron, and high in silicates. The surface clays of this region are directly or indirectly derived from glacial action which accounts for their great variation in composition and thus become a source

of annoyance to large cement companies, for having once located a clay bed the quantity may be unlimited but the quality is frequently unreliable.

The region under discussion has poorly drained areas which could be greatly improved by artificial means. A few large, well located drains are doing excellent service but the large part of the underdrained land remains to be improved by tiling. As the country is becoming more closely settled these conditions are slowly creating a market for home-made tile, which could be manufactured from some of the abundant clay deposits. Several good brick yards are in operation but the demand for bricks is not strong.

The clay from the Standish brick yard is taken from a four foot bed of slightly pebbly glacial clay which shows by analysis a small percentage of lime but still has many small limestone pebbles which prove deleterious to three per cent of the bricks made. In some of the finished product the lime on exposure to air and moisture slacks, in this manner softening and disintegrating the brick. Blowholes caused by escaping gases are also present. If the clay was carefully crushed and perhaps screened or washed as at Sebewaing to free it from all pebbles a much better product would be secured. More experience and a better demand for the brick will no doubt remedy all of the difficulties. The following illustrates the composition of clay from this brickyard which is north of Standish on the Pine river:

SiO_2	37.36	39.10
CO_2	17.16	16.38
Fe_2O_3	3.36	5.60
Al_2O_3	20.02	9.39
CaO	17.79	16.42
MgO	3.28	4.06
Organic Matter	1.03	9.14

At Alger, on the Michigan Central, a light sand exists on a heavy clay which is seen east of the station one mile, on the eastern part of Sec. 10, T. 20 N. and 3 E. This clay is high in Mg and very gritty. It is too calcareous for cement purposes. It might make a fair tile or brick material as the following analysis shows:

SiO_2	39.00
CO_2	19.82
Fe_2O_3	3.12
Al_2O_3	13.16
CaO	15.37
MgO	2.01
Organic	8.52

A clay deposit occurs one and one-half miles west of Sterling, which is in Arenac county on the Michigan Central. This is free of pebbles and has a high percentage of magnesia and silicon oxide. At Summit, which is northwest three miles on the railroad from Sterling, clay has been formed into a moraine and is very high in MgO.

An extensive bed of brownish colored clay constitutes the bed and parts of the banks of Manfield's creek at Shearer, which is on the

abandoned line of the Detroit and Mackinac railroad. Several years ago an attempt was made to produce a suitable brick and from an examination of a large number which were burned from this clay it shows that a good brick was produced, but the lack of demand prevented further work. The clay is very high in aluminum and the first of this element produced in Michigan was manufactured from clay taken from this deposit.

A small brick and tile yard was started at Omer in Arenac county and after a few trials has been inactive. The clay used was taken from near the Rifle river and east of the railroad bridge. This clay is of a fine quality for the above purposes and such an industry on a small scale might find a market for its output in Au Gres, Turner and Twining.

South of Tawas City in Iosco county, in Sec. 2, T. 21 N., R. 7 E., is a 40-foot clay terrace which is covered with sand. In some of the deep ravines of transversing creeks a solid bed of pebbly clay is exposed. The clay is slightly calcareous and contains a small percentage of sand. Over twenty years ago bricks were made here from clay taken from the side of the terrace and several house chimneys were built from these bricks and they have proved to be of excellent quality. Some trouble was experienced with lime. This might be a favorable place for investment of a small capital, for at present bricks would find a market.

North of Tawas City in Sec. 22, T. 22 N., R. 7 E., an attempt was made to build a schoolhouse from bricks made of clay obtained from northeast corner of this section. The clay is of medium quality but poor brick have been produced by underburning and too much sand. At Harmon City in Sec. 24, T. 20 N. and 7 E., occurs a bed of very plastic clay which has been used by masons at Tawas City and Au Sable for lining the arches under boilers and serves the purpose of a medium fire clay. This deposit is low in lime and high in oxides of aluminum and silicon. This clay has the following analysis by F. S. Kedzie:

SiO_2	58.85
Al_2O_3	14.45
Fe_2O_3	7.60
$CaCO^2$	2.94
Mg O	.86
SO_2	1.73
K_2O	2.54
Water of combination	7.50
Organic matter	3.43

The following analysis of clay by H. & W. Heim, of Saginaw, represents a similar deposit:*

S_iO_2	54.5
Al_2O_3	24.85
Fe_2O_3	7.2
CaO	2.95
Mg_2O	1.75
SO_2	1.33
Loss on Ignition	6.5

* This clay occurs in connection with gypsum in the Lower Grand Rapids series and has a high shrinkage and would for brick take quite a little sand, but makes an excellent red brick, suitable for face and perhaps paving brick.

Experiments were tried with the clay for brick manufacture at West Greenbush in Alcona county. At the old pit the clay which was used is surface material of a brownish gray color, containing few pebbles of limestone and a large number of pure lime segregations. The bricks which were made contain too much lime and are easily weathered.

Several other regions might be mentioned which would serve as sources of supply for suitably manufacturing clays and road material. At many points on the Rifle river are 15-foot banks of solid smooth plastic clay, which is calcareous and in many places entirely free of pebbles. The only practical use made of these deposits as yet is for road material.

Many extensive clay deposits exist about Prescott, Lupton, Rose City, Styles lake and Edwards lake of Ogemaw county: Near Loon lake, Taft, Emery Junction, Vine and Tawas City are formations which would repay careful investigation.

§ 7. *Agricultural Resources.*

The real wealth of this region lies in the abundant fertility of the gently rolling country and the level plains of the old lake bottoms. The settlement of many districts has been delayed by the general belief that the land was worthless after the pine was removed. It might be safely asserted that land which has produced white pine or hardwood will meet the needs of agriculturists. Of course there are large tracts of sand barrens which have produced only the familiar jack pines, huckleberry bushes and sweet ferns. These jack pine plains are often so picturesque, entirely free of stone and stump, and so finely located on the banks of streams, that one is charmed. Perhaps in this way many settlers first chose such poor locations. The evidences of attempts made at farming years ago are found in many parts of these plains.

The sand of the jack pine plains is light and easily worked into a shifting powder which renders travel very difficult. Heavy frosts occur in every month of the year and precipitation is insufficient in dry time to keep alive any vegetation but hardy bush plants. The country south of the Rifle river to a line connecting Omer and Sterling is of this description and furnishes a serious obstacle to travel between Standish and the Maple Ridge country. The lands south of Wells creek and east of the Michigan Central railroad in Arenac county are perfectly level and covered with jack pine, huckleberry bush and sweet fern to near Dunham. In many places on all of the jack pine plains are small swamps with big growths of cedar, sedges and marsh grass.

In addition to the jack pine plains there are regions from which pine has been taken, its fertility depending upon its location and method of handling. On many of the old lumbering tracts the stumps offer a serious obstacle to the man who begins farming in a small way and many acres of fertile lands are idle because of the existence of a large amount of unpaid taxes and the cost of removal of pine stumps.

Old burnings are regions over which the fire has swept and left the soil without its natural vegetable mould. Sandy lands are often rendered useless in this manner, while clay soils are uninjured. We also find in this region large tracts of sandy swamps, black ash swales, and cedar thickets along the rivers' banks.

Arenac county is supplied with an abundance of good lands but the

northwestern part of Clayton township, parts of upper Whitney, northwestern corner of Arenac, northern section of Deep River, and parts of both Adams and Moffatt will furnish poor farms.

In Iosco county the jack pine plains have the following general distribution in townships—nearly all of Oscoda, which is the northern tier of townships in the county, parts of Wilbur, Plainfield, and north edge of Tawas. The territory adjoining the Au Sable river through the county is practically useless for farming, except that the river's flood plain furnishes excellent soil.

The entire southeast corner of Oscoda county is poor land, and Alcona county contains only small areas of jack pine plains.

To carefully locate the excellent land under cultivation and give the characteristics of the soil would require more space than this brief report allows. A few notes will be given of those places which, if given care, would make excellent farms. The first place to devote attention is the region north of Duck lake in Au Gres township of Arenac county. The drainage is imperfect and renders useless over fifteen sections of land which would make excellent hay or truck farming soil, for the material is a rich loamy muck. Duck lake is very shallow and its outlet must be deepened or a ditch cut to the Rifle river. Along the entire course of the main stream and east branch of the Au Gres river are many acres of clay lands which would require stumping and draining, but would furnish excellent lands. Especially fine locations of state lands can be found here and for reasonable terms good places can be secured near railroad crossings of the river. The lands are so cheap that a few thousand acres fenced in for cattle grazing ground would be sure to return handsome profits.

A large area of clay loam land is six miles west of Standish and is settling rapidly. The large swamp which is one mile west of Moore's Junction furnishes vast quantities of hay and an extensive tract of this with some of the adjoining sand plains would serve the purpose of a cattle ranch. Northeast of Alger in Moffatt township, the characteristic morainal country is present. This is furnishing fine land to a few settlers and the region would accommodate many more.

Starting south of Melita is a broad strip of clay country, with morainal topography, which extends to Maple Ridge, where fine land has been well developed. This belt passes on north into Ogemaw county to Prescott, thence across the townships of Richland and Logan where the fertile belt turns into Iosco county, covering the southern half of Thompson township and the western half of Plainfield township. The belt appears on the north side of the Au Sable river in Alcona county at Vaughn. Here settlements are being rapidly made on the excellent clay loam soil. Alcona county is nearly three-fourths fair to good agricultural land.*

It is regretted that mention cannot be made of the sugar beet soil, the potato land, and various matters which would stimulate the settlement of lands which now lie idle. Only an attempt has been made to mention those lands suitable for farming, and waiting settlers, no reference has been made of the abundance of lands already under cultivation. It is hoped these brief notes will lead some to investigate and settle in a region whose fertility can no longer be questioned.

* About 300 square miles good farming land, 300 square miles good grazing land, 65 square miles jack pine land.

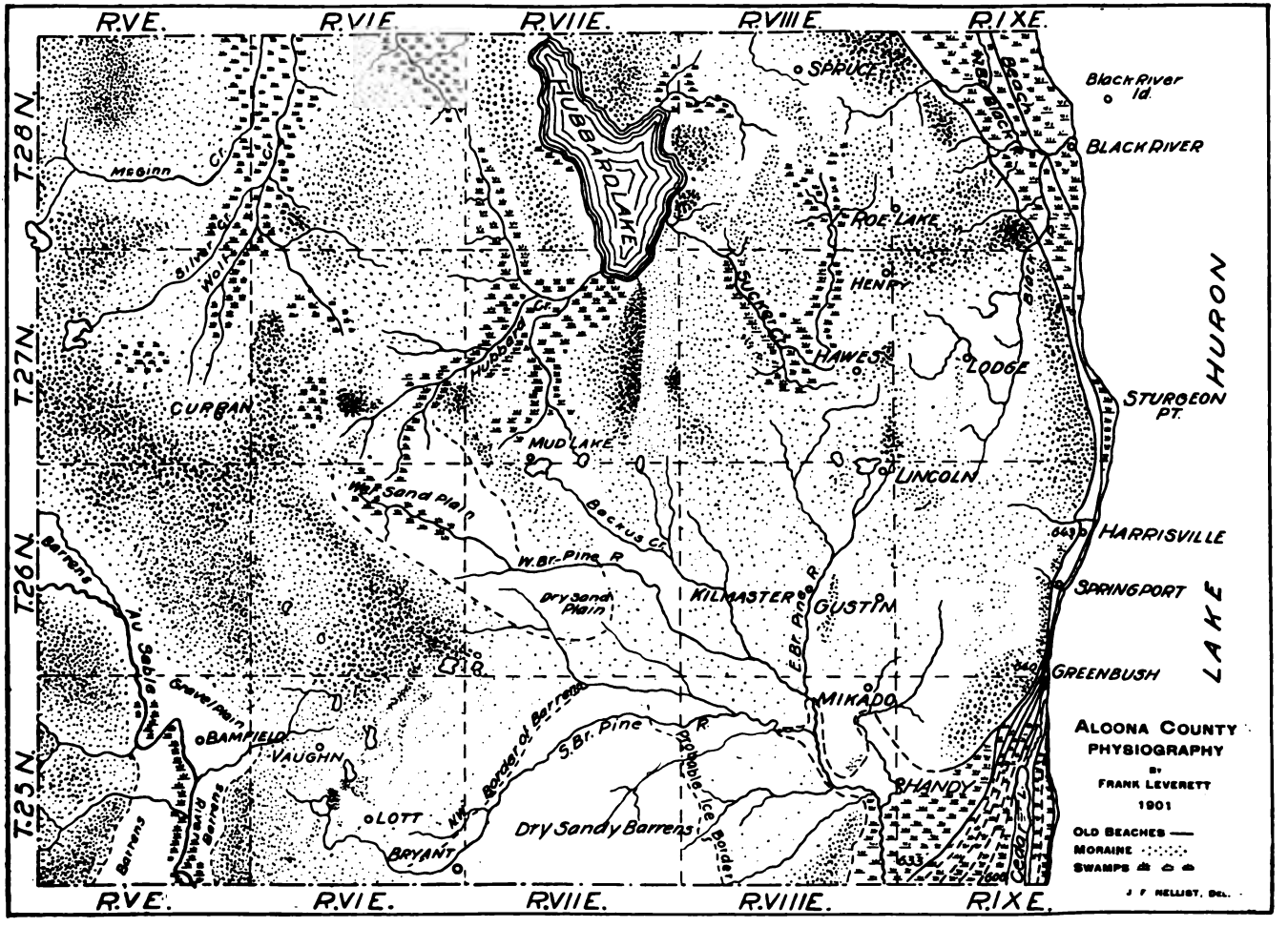
ALCONA COUNTY, MICHIGAN

SURFACE GEOLOGY

BY FRANK LEVERETT

SUBSURFACE GEOLOGY

BY A. C. LANE.


R.V E.
R.VI E.
R.VII E.
R.VIII E.
R.IX E.
T.28 N.
T.27 N.
T.26 N.
T.25 N.
HUBBARD LAKE
SPRUCE
Black River Id.
BLACK RIVER
McGinn Cr.
Silver Cr.
Wolf Cr.
ROE LAKE
HENRY
Sucker Cr.
HAWES
LODGE
STURGEON PT.
HURON
LAKE
CURRAN
Hubbard Cr.
MUD LAKE
LINCOLN
Mud Lake Sand Plain
Bectus Cr.
HARRISVILLE
W. Br. Pine R.
SPRINGPORT
Barrens
Dry Sand Plain
KILMASTER
GUSTIN
E. Br. Pine R.
GREENBUSH
MIKADO
Gravel Plain
BAMFIELD
VAUGHN
S. Br. Pine R.
Boundary of Barrens
HANDY
LOTT
Dry Sandy Barrens
Rabbit Ice Border
BRYANT
ALCONA COUNTY
PHYSIOGRAPHY
BY
FRANK LEVERETT
1901
OLD BEACHES
MORAINE
SWAMPS
J. F. NELLIST, DEL.

CONTENTS.

SURFACE GEOLOGY. Page.

Introduction ... 35
Situation and area ... 35
Settlement and population ... 36
Transportation facilities ... 37
Previous geological work ... 37
Scope of the present investigation ... 38

Climate ... 39
Physiography ... 41
Topography ... 41
Altitudes ... 42
Drainage ... 44
Lakes ... 45

The Glacial Deposits ... 45
General statement ... 45
Moraines and ice borders in Alcona county ... 46
The outer border drainage ... 47
Thickness of the drift ... 48
Structure of the drift ... 49

The Lake History ... 51
Predecessors of Lake Algonquin ... 51
Lake Algonquin ... 53
The Nipissing Great Lakes ... 54
Lake Huron ... 54

Economic Resources ... 55
Soils ... 55
Wells ... 58
Marl ... 60
Clay ... 61
Water power ... 63

SUBSURFACE GEOLOGY ... 64
Killmaster wells ... 65
Alpena county wells ... 67
Au Sable and Oscoda wells ... 69

Economic Geology ... 71
Oil and gas possibilities ... 71
Salt ... 74
Water and mineral water ... 75
Peat ... 75
Rumors of coal and lead ... 75

ALCONA COUNTY.

During the year Mr. J. H. Killmaster of Alcona county wrote to the Survey, inquiring as to the possibility of a survey of that county. I pointed out to him that we were working that way, but that we had not money enough to take up that county, without dropping something of equal importance. So he brought the matter before the Board of Supervisors with the result that they voted $200 to be expended under my supervision. This money was largely expended in employing Mr. Leverett, one of the most expert surface geologists in the United States, who was fortunately for us engaged on work for the United States Survey at West Branch and was courteously released for a time by them, so that no heavy bill for traveling expenses was incurred. Mr. Killmaster also, by giving the free use of his team of horses, saved the county many dollars. We also had made analyses of certain products. The report of the county was necessarily brief, and coming out of order in our studies, may need some revision when adjacent counties are complete. The report handed to the Board of Supervisors, which follows, is therefore necessarily incomplete.

REPORT ON THE SURFACE GEOLOGY OF ALCONA COUNTY, MICHIGAN.

BY FRANK LEVERETT.

INTRODUCTION.

Situation and area. Alcona county is situated on the border of Lake Huron in the northeast part of the southern peninsula of Michigan. Its south border is near latitude 44° 30′ and its north border about latitude 44° 50′. The border counties are as follows: Alpena on the north, Oscoda on the west and Iosco on the south. It embraces sixteen full and four fractional townships, the latter being along the shore of Lake Huron. Townships 25 to 28 N. and ranges 5 to 9 E., inclusive, fall within its limits. The area is about 690 square miles. The land surface is, however, somewhat less for there are several lakes in the county. The largest, Hubbard lake, has an estimated area of thirteen square miles, and the combined area of all the lakes probably reaches twenty-five square miles, thus leaving an area of about 665 square miles of land surface.

Alcona was organized into an independent county in 1869. It was attached to Cheboygan county from 1853 to 1857, to Alpena county in 1857 to 1858, to Iosco county in 1858 to 1859, and again to Alpena county from 1859 to 1869. From 1859 to 1866 it constituted but a single civil township of Alpena county, the township of Harrisville. Alcona township was cut off in 1866 and Greenbush in 1868. There were thus three civil townships at the organization of the county. At present there are eleven civil townships in the twenty land survey townships distributed as follows:

Curtis, in T. 25 N., Rs. 5 and 6 E.
Mikado, in T. 25 N., Rs. 7 and 8 E.
Greenbush, in T. 25 N., R. 9 E.
Millen, in T. 26 N., Rs. 6 and 7 E.
Gustin, in T. 26 N., R. 8 E.
Harrisville, in T. 26 N., R. 9 E.
Mitchell, in T. 26 N., R. 5 E., T. 27 N., Rs. 5 and 6 E., and T. 28 N., R. 5 E.
Hawes, in T. 27 N., Rs. 7 and 8 E.
Haynes, in T. 27 N., R. 9 E.
Caledonia, in T. 28 N., R. 6 E., and north half of T. 28, Rs. 7 and 8 E.
Alcona, in T. 28 N., R. 9 E., and south half of T. 28, Rs. 7 and 8 E.

Settlement and population. Situated as it is on the shore of Lake Huron, fishermen came to this county in advance of actual settlers. They wandered from place to place and built temporary dwellings or camped in the open air. The fishermen in some instances cultivated small garden patches, and one (S. M. Holden) started a cooperage business on the site of Springport, to supply barrels in which to ship the fish. There were fishing stations at the cove near Alcona postoffice, at the high banks where Springport now stands, and at Greenbush, which were thronged at an early date with fishermen. There seems to have been no other industry from the arrival of the first fisherman (thought to have been William Collins), about 1835, down to 1854, when the first sawmill was built. This mill was put up at Harrisville by two fishermen, Crosier Davison and S. M. Holden, but was soon sold to Benjamin Harris and sons, the persons after whom Harrisville was named. It utilized the power afforded by the small stream which enters Lake Huron at this village.

The first school was started in 1860, and was taught in the loft of the Harris store. The following year religious meetings were first conducted, the preacher being C. J. Merchant, a Methodist itinerary. The first physician was Dr. John Lyman, and the first lawyer, R. Z. Roberts.

In 1866 the Harris firm sold out its business to Weston, Colwell & Co., a firm with more capital, who gave the lumber business a fresh impetus and brought in a number of new families. The same year systematic efforts were made to induce settlers to clear up farms and develop the valuable agricultural resources. Roads were soon surveyed, stumps pulled and turnpikes constructed that aided materially in opening up the country to settlement.[1]

The lumbering industry was pushed so vigorously by several lumbering firms that the country was soon stripped of its rich growth of timber. The valuable agricultural lands were recognized as such by the woodsmen, many of whom have with profit abandoned lumbering and taken up farming. A population of less than 6,000 is now spread over a county whose soil will easily support two or three times that number.

The growth of population is shown in the following figures, taken from the United States Census reports: Population, 185 in 1860; 696 in 1870; 3,107 in 1880; 5,409 in 1890, and 5,691 in 1900. There are at present about eight persons to the square mile. Only four other counties in the southern peninsula have a thinner settlement and these are all far below Alcona in agricultural resources. The fact that the villages of Alcona county are very small should be considered in dealing with the subject of thinness of settlement. Harrisville, the county seat and largest village, had in 1900 a population of but 403, and the combined population of the villages scarcely reaches 1,400, or about 25 per cent of the entire population. The decline of the lumber industry has affected the villages unfavorably, some of them having shown a marked decrease between 1890 and 1900. But the growth of farming has been such as to more than offset this decrease so that the population was slightly greater in 1900 than in 1890.

[1] For many of the facts concerning early settlement I am indebted to a pamphlet of 12 pages entitled "A brief history of the county of Alcona, Michigan" prepared by Charles P. Reynolds of Harrisville and published by the Harrisville Review Printing Office, in 1877. See also History of the Lake Huron Shore, H. R. Page & Co., Chicago, 1883.

Transportation facilities. The transportation facilities are excellent in the better settled eastern and southern parts of the county. There are docks and landings for steamers at convenient intervals on the shore of Lake Huron and a regular boat service in the summer months. The Au Sable & Northwestern railroad (narrow gauge) passes through the settlement in the southwest part of the county, and connects with the Detroit & Mackinac railroad at Au Sable. There is also an unobstructed river from where the Au Sable enters the county to its mouth at the village of Au Sable, which is extensively utilized for rafting timber. The Detroit & Mackinac Railroad Company has an old line passing from Black river southward to Au Sable through Lincoln and Mikado, and has constructed a new line along the shore the present year which gives Harrisville and Greenbush a much needed railway service.

During the lumbering period there were several lines running into the central and western parts of the county which were abandoned with the decline of the lumber industry. The graded beds are, however, easily changed into wagon roads by the removal of the ties, and in some cases they have been pressed into service without the labor of removing the ties. Such roads are, however, a torture to the traveler as the writer has had occasion to experience. In this connection it may be remarked that throughout much of the county improvement in wagon roads is needed.

Previous geological work. There being no outcrops of rock in Alcona county it has received but little attention from geologists. The county was explored to some extent by the first State geologist, Douglass Houghton, in 1838 or earlier, for he touches upon its salient topographic features in his second annual report, submitted in February, 1839. After discussing the general features of the region north of Saginaw Bay he remarks:[1]

"An exception to the flatness of the country exists in an elevated district commencing in high hills a little south of Thunder Bay river and stretching in a southwesterly direction toward the head of Lake Michigan. This range at its commencement is usually known as the highlands of the Au Sable."

Attention is called by Houghton to ledges of limestone near the mouth of Thunder Bay river, which would be a barrier to the navigation of that stream, but he found nothing of the sort on the lower course of the Au Sable, and suggested the feasibility of navigating the stream unless it should prove to have too much shifting sand. The reconnaissance made by Houghton seems to have given him a false impression of the agricultural conditions of this region for he remarks that it is "ill adapted to the purpose of agriculture, being composed chiefly of sandy ridges with intervening swales, and rising so gradually toward the central part of the State as to leave the country extremely flat." This remark would apply only to a small part of the surface, but as that part is situated along the streams and the lake shore, that is, in places most accessible to the early explorer, it would naturally stamp the whole region unfavorably. In this connection it may be remarked that the prevalence of pine forests has tended to perpetuate the unfavorable

[1] Senate Documents Michigan 1839, p. 267; also House Documents Michigan 1839, p. 383.

name which this region so early received for it has been generally supposed that pine grows only on barrens. It remained for the settlers to demonstrate by abundant crops and the general evidences of thrift that this and other regions with pine timber really have a large amount of productive land.

So far as known to the writer no geological work of note was done in this region from the time of Houghton's reconnaissance down to 1895, when F. B. Taylor made a trip along the shore of Lake Huron from Mackinaw to Saginaw Bay to determine the number and altitude of the old shore lines. He found two well defined beaches above the present one in the district north of the Au Sable river.[1] Taylor also found that higher beaches which are present in the Saginaw basin are not present in Alcona county and the county to the north, because this northern region was still covered by the great ice sheet.

State Geologist A. C. Lane made a trip through the southwest part of Alcona county in 1897, notes upon which are presented in a bulletin on the water resources of Michigan published by the United States Geological Survey.[2] These notes refer to water power on the Au Sable river, which is said to be excellent but unused, to the general topographic features and to the favorable conditions for obtaining flowing wells on the southern slope of the elevated tracts which traverse the western part of the county and extend southwest across Ogemaw and Clare counties.

Scope of the present investigation. An allotment having been made by the board of county supervisors in October, 1901, for an examination into the resources of Alcona county under the direction of the State Geologist, the present writer was engaged to proceed at once to the field and collect the necessary data for a report upon the character of the soils, the occurrence of marl or clay, of notable value, the conditions and prospects for flowing wells, and the general distribution of underground water, and to obtain such data as the region affords that will bear upon the underlying rock formations. The investigation is similar to that already made in central and southern Michigan under the United States Geological Survey, but the present report enters more into detail concerning the resources of the county than is practicable in the more general and comprehensive report in preparation for the United States survey. The field work was done in October and the early part of November, and for its rapid and easy prosecution the writer is indebted to the several members of the board of supervisors and to a number of other citizens, notably J. H. Killmaster, Edward Chapelle, Charles Conklin, George Rutson, L. A. Colwell, E. M. Larson, D. W. Brooks and C. W. Goodsell. Indebtedness is also acknowledged to the Detroit & Mackinac and the Au Sable & Northwestern railroads for transportation over their lines and for valuable data.

Owing to the undeveloped condition and lack of roads in the western half of the county the examination was necessarily less detailed than in the more highly improved eastern part, but this deficiency has been partially filled by information furnished by supervisors and other old residents.

---

[1] For discussion of these beaches see American Geologist Vol. 17, 1896, pp. 253-257. Also Dryer's Studies in Indiana Geography, Inland Pub. Co., Terre Haute, Indiana, 1897, pp. 90-110.

[2] Water Supply and Irrigation Papers of the U. S. Geological Survey No. 30, Washington, Government Printing Office, 1899. See especially pages 20, 73-75.

CLIMATE.

The effect of the great lakes in modifying the climate of the bordering districts is a subject which has been thoroughly considered and ably discussed by one of the early State geologists of Michigan, Alexander Winchell, first in his report of progress for 1870, and subsequently in Harper's Monthly and in Walling's Atlas of Michigan, and in a separate publication entitled "Michigan." The subject is so complicated that space will not permit full presentation, and we can do little more than outline a few of the conditions prevailing in the particular region under discussion.

It is found that in winter the isothermal lines or lines of equal temperature are much farther south in the interior of the southern peninsula than on the borders by Lake Huron and Lake Michigan. It is no colder at Harrisville on the shore of Lake Huron and at Traverse City on a bay of Lake Michigan, each about latitude 44° 40′, than at Flint and Owosso in the south central part of the State near latitude 43°. But the winter mean temperature at Harrisville is nearly three degrees warmer than at Grayling, a town in the same latitude in the interior of the State, as shown in the table below. In cold waves the contrast is often much more striking than that of the mean temperature. Thus the coldest wave that has been experienced in Michigan in the past 12 years was that in February, 1899, when the thermometer at Harrisville dropped to 25° below zero; but this was 16° warmer than the record at Lake City and Grayling, and 18° warmer than at Mancelona as reported in the United States Weather Review for that month. In the 12-year period just referred to there have been but three months in which the temperature at Harrisville has fallen lower than 20° below zero, but the interior of the State has experienced such a temperature in two or more months in nearly every winter. The following table of temperatures at Harrisville and Grayling for the four winter months, December to March inclusive, in the past five years, will serve to show the contrast between the shore and the interior, as well as the variations at each place. Grayling is in the same latitude as Harrisville and 70 miles west.

TABLE OF AVERAGE WINTER TEMPERATURES.

(Compiled from U. S. Monthly Weather Review.)

Period.	Harrisville.	Grayling.
	Deg. Fahr.	Deg. Fahr.
Winter of 1896-7	24.4	21.4
Winter of 1897-8	25.1	22.8
Winter of 1898-9	19.0	15.6
Winter of 1899-1900	21.2	19.1
Winter of 1900-1	21.4	19.2
Five year average	22.2	19.6

In summer the temperature, as indicated in Winchell's isothermal map, is as high in the interior of Michigan in latitude 44° 40′ (that is the latitude of Harrisville) as it is at the southern ends of Lakes Huron

and Michigan and decidedly warmer than at Harrisville or Traverse City. The map shows the mean summer temperature at Harrisville to be about 63 degrees above zero, while at the headwaters of the Au Sable, near the same latitude, it is 66 degrees. An examination of the Weather Review records at Harrisville and Grayling for the past five years (1897-1901, inclusive) shows the temperature at Harrisville to average 65 degrees for the summer months, while that at Grayling averages 66.4 degrees. The difference, therefore, is slightly less than Winchell's map indicates and is not so striking as that of the winter temperatures given in the table above. In spring and fall the climate is more equable on the borders of the lakes than in the interior of the State. Killing frosts are infrequent after crops are started in the spring or before they ripen in the fall. In the State Geological reports for 1839 to 1841 Douglass Houghton and his assistants made references to the fact that the Indians had grown corn successfully on the borders of the Great Lakes in several of the northern counties of the southern peninsula. Fruit growers have also found that the lake borders are the most favorable parts of the State for orchards. The thrifty apple orchards of Alcona county bear strong testimony to the favorable climatic conditions.

The following records of temperature and precipitation taken from the United States Monthly Weather Review for 1900 serve to indicate the ordinary conditions at Harrisville, except that precipitation is remarkably low for the month of June. As no station for weather observations has been established in the back part of the county or for some distance farther inland, the departure from conditions at Harrisville in that part of the county is not known.

TABLE OF TEMPERATURE AND PRECIPITATION AT HARRISVILLE, MICHIGAN, FOR THE YEAR 1900.

(Compiled from U. S. Monthly Weather Review.)

Month.	Maximum Temp.	Minimum Temp.	Mean Temp.	Precipitation.	(a) Snowfall.
	Deg. Fahr.	Deg. Fahr.	Deg. Fahr.	Inches.	Inches.
January	48	—14	22.8	1.24	8.5
February	55	—17	15.8	4.19	23.2
March	47	—5	22.1	2.05	20.5
April	75	20	42.2	1.36	.....
May	90	34	52.0	2.64	.....
June	96	37	61.2	0.53	.....
July	97	45	66.6	4.34	.....
August	98	52	69.8	5.23	.....
September	93	38	63.4	2.25	.....
October	79	28	56.7	2.90	.....
November	62	10	35.8	3.01	3.7
December	47	—3	25.4	1.37	9.5
Yearly	.....	.....	44.3	31.11	65.4

(a) The snowfall is included in the column showing precipitation.

The rainfall of this county is not more likely than temperature to be ill adapted to the needs of crops. The yearly precipitation is usually between 30 and 40 inches, and of this a sufficiently large part falls in the growing season to keep the soil in good condition for crops.

PHYSIOGRAPHY.

Topography.—A glance at the map of the surface features of Alcona county (Plate I) will serve to show that the northern and western parts of the county are largely occupied by hills or belts of rolling land, while the southeastern portion, mainly in the Pine river drainage basin, is a comparatively level district. An examination of the list of altitudes given below will bring out the heights which are found in various parts of the county. The datum to which points in this region are commonly referred is the surface of Lake Huron, whose mean elevation is nearly 580 feet above sea level. Referring to the altitudes, it will be seen that the highest point crossed within the county is, by barometric measurement, 1,260 feet above the sea, or 680 feet above Lake Huron. Possibly other points in the western part of the county rise a few feet higher, but it is doubtful if any exceed 1,300 feet. There is within the county an area of perhaps 40 square miles that stands above 1,000 feet, mainly in the western part. A large area, comprising probably three-fourths of the county, stands between 700 and 900 feet above the sea. There is but little low land along the edge of Lake Huron, for along much of the shore a rise of 100 to 175 feet is made in passing back a mile or less. On the north border, however, the low land extends three miles and on the south border fully five miles back from the lake. In general the highest land or backbone of the county constitutes the divide between the north flowing and south flowing streams, if we disregard Black river, and trends in a southwest course from the south part of T. 28, R. 9 E., to Lincoln and thence westward to the county limits. The hills in the south part of T. 28, R. 9 E., and those along the border of T. 27, Rs. 8 and 9 E., reach an altitude 300 to 325 feet above Lake Huron. Points in the east part of T. 27, R. 7 E., reach an altitude 400 to 425 feet above the lake, but with this exception the altitude in Rs. 7, 8 and 9 E. is less than 400 feet above lake level With the exception of valleys and narrow strips of low plain bordering them, the western part of the county for a distance of eight to twelve miles from the west border rises more than 400 feet above the lake. This elevated part is shaded heavily on the map (Plate I) and the strength of shading is graduated to the prominence of the hills. In the Pine river drainage basin there is a gradual rise from the lake shore to the headwaters of the various tributaries.

The relief of the ridges and hills above the valleys and basins which they border or inclose seldom exceeds 300 feet and is usually 100 feet or less. Hubbard lake, which stands about 680 feet, is bordered by hills whose altitude ranges from 750 feet or less up to about 950 feet above the sea. The majority of the lakes stand much higher than Hubbard lake. Several near Vaughn are about 950 feet, Mud lake and others near it 875 to 900 feet and those near Lincoln about 770 feet. The hills near Vaughn lake and its neighbors reach about 1,100 feet, those near Mud lake 950 feet, and those around Lincoln 875 feet above the sea. A group of hills in Sec. 28, T. 27, R. 6 E., rises 200 feet above border districts, and Comstock hill in Sec. 25 of the same township is nearly as prominent. There are also some hills about 200 feet high in the southwest corner of the county, and the massive morainic tract forming the

division between the Au Sable and Thunder bay drainage in Tps. 25 and 26 N., Rs. 5 and 6 E., has many hills and ridges which rise abruptly 100 to 200 feet above the bordering basins and sags. A very prominent mass of hills in the northwest part of the northwest township rises fully 300 feet above the valleys on the east and south.

Some of the hills and ridges in the northern and western part of the county are too steep to be easily tilled, but on the whole the slopes are so gradual as to be no hindrance to the cultivation of the land. In nearly every township there are plane tracts of considerable extent, as indicated in Plate I, while several townships in the southeast part of the county are nearly plane.

Table of Altitudes.—The following table of altitudes includes not only the points along the railroad lines which are determined by spirit level, but also a considerable number of barometric determinations. The latter are liable in some cases to contain serious errors, for there were some taken in the western and northern parts of the county which were carried through an entire day's drive, with no opportunity to check results. It so happened, however, that the weather conditions were somewhat steady at that time, so that the errors may prove to be unimportant. The barometric determinations in the eastern part of the county are probably not far from correct.

ALTITUDES ALONG THE OLD LINE OF THE DETROIT AND MACKINAC RAILROAD.

	Feet (above tide level) A. T.
Black River Station	585
Summit 1900 feet northeast of Roe Lake Station	822
Roe Lake Station	810
Summit 1400 feet south of Roe Lake Station	818
Henry Station	795
Summit 2400 feet north of Hawes Station	807
Hawes Station	790
Summit 700 feet south of Hawes Station	797
Summit 1500 feet north of Lincoln Station	798
Lincoln Station	779
Summit 6800 feet south of Lincoln Station	790
Gustin Station	693
Mikado Station	634
Top of grade 4000 feet north of Handy Station	640
Handy Station	624
County line Alcona and Iosco counties	631
Harrisville Junction (in Iosco county)	615

NEW LINE OF DETROIT AND MACKINAC RAILROAD.

Harrisville Junction (in Iosco county)	615
Greenbush Station	640
Summit about 1.8 miles north of Greenbush	648
Harrisville at Main street	625
Harrisville Station	622
Sturgeon Point	614.5
Alcona	602.5
Stony ridge 1.5 miles north of Alcona	621
Black River Station	585

BAROMETRIC DETERMINATIONS.

Bamfield Station on Au Sable and Northwestern Railroad	870* or 850
Au Sable river at bridge, near Bamfield	815* or 810
Vaughn Station, Au Sable and Northwestern Railroad	1023* or 1005
Hill at cemetery north of Vaughn lake	1100
Lott Postoffice	900
Bryant Station, Au Sable and Northwestern Railroad	852* or 835
Knoll cut by old railroad grade in section 7, T. 25, R. 7 E.	880
Swamp south of knoll in section 7, T. 25, R. 7 E.	830
Sand and gravel plain in section 3, T. 25, R. 7 E.	830

* Averages of two or three barometric determinations by A. C. Lane.

	Feet A. T.
Cross roads in northwest corner of T. 25, R. 7 E., near Tubbs' lake	850
Pine river at forks west of Mikado (bluff 640 feet)	620
A. D. McDonald's residence section 9, T. 25, R. 9 E	675
Summit on State road near corners of Tps. 26 and 27, Rs. 5 and 6 E	1260
Road intersection in N. W. part of T. 26, R. 6 E	1070
Plain in Secs. 1, 2 and 3, T. 26, R. 6 E	900-925
Ridge one mile west of Mud lake near postoffice	940
Mud lake, water level	860
Sand plain near center of T. 26, R. 7 E	800
West branch of Pine river, Sec. 25, T. 26, R. 7 E., below dam	675
Township line east of dam	720
Killmaster postoffice	695*
Stream at Killmaster below dam	690*
Killmaster boring No. 1	702*
Killmaster boring No. 2	710
Killmaster boring No. 3, near postoffice	692*
Cross roads one-half mile west of Gustin	660
Pine river on State road, west of Lincoln	725
Upland west of Pine river, middle of line of Secs. 4 and 33	825
Upland near corners of Secs. 4 and 5, T. 26, and Secs 32 and 33, T. 27, R. 8 E	875
Valley at Robinson's farm on State road west of Lincoln	810
Upland in east part of Lincoln	810
Summit in road in Sec. 5, T. 26, R. 9, E	840
County infirmary	705
Mrs. Chapel's residence, one mile south of infirmary	750
Napoleon Sherbeneau's residence, one mile north of infirmary	750
Knoll near center of Sec. 19, Harrisville Tp	710
West line of Sec. 19, at road intersection	695
Middle of line of Secs. 19 and 20, Harrisville Tp	680
Stream near center of Sec. 20, Harrisville Tp	660
Plain at line of Secs. 20 and 21, Harrisville Tp	675
Low knoll near center of Sec. 21, Harrisville Tp	700
Plain at line of Secs. 21 and 22, near jog in road	680
Summit in Sec. 22, Harrisville Tp., on E-W. road	700
Northwest corner of Sec. 34, Harrisville Tp	700
Ridge 2 to 3 miles north of Greenbush	730-755
A. Atherton's residence, Sec. 26, T. 27, R. 5 E	1010
Corner of Secs. 13, 14, 23, and 24, T. 27, R. 5 E	920
Wolf creek, near corner of Secs. 1, 2, 11 and 12, T. 27, R. 5 E	815
Plain in Sec. 2, between Wolf and Silver creeks	840
Dorr's camp in Sec. 34, T. 28, R. 5 E	900
McGinn creek, near corners of Secs. 21, 22, 27 and 28, T. 2 S., R. 5 E	870
Sandy plain north of McGinn creek in Secs. 21 and 22, T. 28, R. 5 E	920
Hill near line of Secs. 8 and 9, T. 28, R. 5 E	1200
Hill in Sec. 28, T. 27, R. 6 E	1165
Nearly plain tracts in Sec. 33, T. 27, R. 6 E	950-965
Range of hills in Secs. 14, 23 and 26, T. 27, R. 7 E	975-1000
Hill on Sec. 24, T. 27, R. 7 E	1000
Lowland between hills in Secs. 23 and 24, T. 27, R. 7 E	875
Sheep ranch in Secs. 30 and 31, T. 27, R. 8 E	875-925
Hubbard lake	680
Upland southeast of Hubbard lake in Sec. 7, T. 27, R. 8 E	850
Sucker creek at line of Secs. 5 and 8, T. 27, R. 8 E	700
Upland on line of Secs. 4 and 9, T. 27, R. 8 E	820
Sucker creek on line of Secs. 2 and 11, T. 27, R. 8 E	740
Upland in road one-eighth mile west of Henry Station	840
Upland at township line east of Henry Station	840
Hill in Secs. 13 and 24, T. 27, R. 8 E	890
Cross roads at middle of line of Hawes and Haynes townships	800
Hill one mile north-northeast of Lincoln	850
Points near line of Secs. 5 and 6, T. 27, R. 9 E	915
Summit in road on line of Secs. 5 and 8, T. 27, R. 9 E	900
C. W. Goodsell's residence, east side Sec. 8, T. 27, R. 9 E	800
Black river, in Sec. 3, near Frank Elmer's residence	675
Frank Elmer's residence in Sec. 3, T. 27, R. 9 E	752* or 735
Summit in road on line of Secs. 17 and 20, T. 28, R. 9 E	800
High points near center of Sec. 17, T. 28, R. 9 E	825
Stream near corners of Secs. 17, 18, 19 and 20, T. 28, R. 9 E	735
Till plain in Secs. 18 and 19, where road leads south	760
Middle of range line between Rs. 8 and 9 E. T. 28 N	775
Stream on range line one mile north of last named point	690
Summit on line of Secs. 1 and 12, T. 28 R. 8 E	840
Alexander McDonald's residence in Sec. 2, T. 28, R. 8 E	860
Summit near middle of line of Secs. 2 and 11, T. 28, R. 8 E	880
Spruce postoffice, corner of Secs. 3, 4, 9 and 10, T. 28, R. 8 E	750
Cross roads one mile south of Spruce	770

BAROMETER DETERMINATIONS BY A. C. LANE.

	Feet A. T.
Flat Rock Station	860*
Au Sable, near Flat Rock	830
Gravel table lands near Bamfield	970
River, near Bamfield	812*
Terrace, near Bamfield	840
Bamfield Station	870
Faint river terrace back of Bamfield Station	900
Bryant, sand plains around	852*
Batton, edge of clay	900
Vaughn	1023*
Chevriers	990*

Drainage.—The drainage of Alcona county is nearly equally divided between the Thunder Bay river and Au Sable river systems, the north half being drained northward to Thunder Bay river and the south half southward and eastward to the Au Sable river. There is a narrow strip on the border of Lake Huron drained by Black river and other small direct tributaries of the lake.

The Au Sable river crosses the southwest corner of the county, but receives no important tributaries in that part of its course. Pine river, with its numerous tributaries, drains about six townships in the southeastern part of Alcona county, and enters the Au Sable in Iosco county. Its main forks are known as South Branch, West Branch and East Branch. Other important tributaries are McGillis creek, Backus creek and Van Etten creek. The South Branch, West Branch and McGillis creek all find their sources in the high belt of hills in range 6 in the western part of the county, and have a general eastward course across a plain in range 7 to the middle of range 8. Here, after receiving Backus creek and East Branch, the course is southward into Iosco county. Backus creek heads in Mud lake near the center of the county and flows southeastward across a plain in T. 26, Rs. 7 and 8 E., to join the West Branch in Sec. 33 of the latter township. East Branch, with its several headwater tributaries, drains the south part of T. 27 and the east part of T. 26, R. 8 E., and unites with the West Branch in Sec. 3, T. 25, R. 8 E. Van Etten creek drains the southwest part of T. 26, R. 9 E. and the adjoining parts of T. 25, Rs. 8 and 9 E., and enters Pine river in T. 25, R. 8 E.[1]

The principal tributaries of Thunder Bay river in Alcona county are Hubbard lake with its main affluents, Sucker creek and Hubbard creek, which drain much of T. 27, Rs. 6, 7 and 8 E., and T. 28, Rs. 7 and 8 E., and Wolf creek and its tributaries, McGinn, Silver and Wild Cat creeks, which drain much of T. 27, Rs. 5 and 6 E., and T. 28, Rs. 5 and 6 E.

Black river has two forks, known as the North and South branches. The South or main branch drains much of T. 27, R. 9 E., and adjoining parts of Tps. 26 and 28, R. 9 E. The North Branch drains the northeast part of the county in T. 28, Rs. 8 and 9 E., and a small adjoining district in Alpena county.

There are a few small direct tributaries of Lake Huron south of the

* Average of at least two, one or more corrected by comparison with self-recording aneroid at a fixed point.

[1] This tributary of Pine River has received the same name which is applied by the residents to the main stream after it enters Iosco county, there being in that county an expansion of Pine river called Van Etten lake, which has led to the extension of the name Van Etten to part of the stream below Van Etten lake. This seems an unnecessary element of confusion which might be easily remedied by ceasing to call the lower course of Pine river Van Etten creek.

Black river drainage basin, the most important of which is Cedar lake outlet, which discharges at Greenbush, and a small stream that enters the lake through the village of Harrisville.

The streams are in places bordered extensively by swamps. This is conspicuously the case in those tributary to Hubbard lake, and is a common feature on several other streams. Extensive swamps also occur in the northeast and southeast parts of the county in the low plain, which has been at some time beneath lake level.

A large part of the swamp land, when cleared of logs and brush and properly ditched, may be drained sufficiently to become good farming land. This has already been done in a part of the Pine river drainage basin.

Lakes.—The lakes of this county are inadequately represented on any maps which have yet been made, and a special survey is needed to determine their position and extent. The plats of the government land survey show only those which were crossed by section and quarter lines, and but a few of these were meandered and accurately platted. The lakes which do not appear on the government plats are necessarily small, for each must fall within the quarter-line limit, but they form an important factor in determining the value of the grazing lands which border them and are so numerous as to supply the needs of much of the grazing district in the western and northern parts of the county. They usually constitute the head of streams, but a few are expansions of streams and a few have no outlet.

For attractive scenery, Hubbard is scarcely surpassed by any of the large inland lakes of the State. The body of water, seven miles in length and nearly two miles in average width, is bordered on all sides by ranges of hills with diversified outline and altitude, which at present are the haunts of deer and other wild game, but which may become valuable grazing lands. The body of water itself and its gravelly beaches will no doubt in time become one of Michigan's popular summer resorts. Already the building of an electric road to it from Alpena is being agitated, and the Thunder bay lowland, which extends back nearly to this lake, affords an easy line of access for such a road. For the variety and quality of its fish the lake already has a high reputation.

Other attractive lakes are those around Lincoln and the chain near Vaughn (Glennie postoffice), all of which are bordered by undulating uplands and gravelly or sandy beaches. But nearly every lake possesses attractive features and contributes to the pleasure both of resident and traveler.

THE GLACIAL DEPOSITS.

General Statement.—It is a well established fact that a moving ice sheet, such as now covers Greenland and gravitates from the interior toward the border of that great island, has in a comparatively recent geologic period covered eastern Canada and pushed southward across Michigan and adjacent states to the vicinity of the Ohio river. In the basal portion of the ice sheet there was a large amount of earth and stones which it had gathered along its path. The ice appears to have become overburdened with this load and to have dropped much of it as it advanced, building up a bed beneath it known as the ground moraine.

The remainder it carried to the end of its course, and there heaped it up as a terminal moraine, similar in many respects to the moraines now forming on the borders of the Greenland ice sheet, or the glaciers of Alaska, or of the Alps. When the ice melted off from the country there was not a continuous and steady shrinking of the ice field, but places where the margin remained nearly stationary for a period sufficiently long to enable the ice to bring large amounts of material and heap up other terminal moraines inside the limits of those already formed. In this way several moraines were formed before the ice had melted off from Michigan.

The glacial history is not so simple as to be comprehended in a single great invasion and disappearance of the ice sheet with the halts made in its waning stage. Studies in the interior of the Mississippi basin in Wisconsin, Iowa, Illinois and Indiana have brought to light several distinct sheets of drift, each marking a great ice invasion, which differ much more widely in age than the successive moraines just mentioned. These sheets are not exposed to view in Michigan because the latest ice invasion extended over the entire State and left so heavy a deposit of drift as to effectually conceal any earlier drift sheets which may be present. It is, therefore, only in deep excavations and perhaps in a few valleys that the earlier sheets would be reached. Yet commingled with the drift of the last invasion there are copper nuggets and possibly other materials from the northwest, which must have been brought here by an earlier and independent invasion. As yet no separation of drift sheets has been made within the limits of Alcona county, and the earlier glacial history receives, therefore, only this passing notice.

The sinuous or looped course of many of the moraines serves to show that the movement of the ice sheet was greatly influenced by inequalities in the surface of the country over which it passed, there being more free and rapid movement through low districts, such as the basins occupied by the Great Lakes, than over the bordering higher land. This resulted in the production of ice lobes that have received names from the basins in which they deployed, as Lake Michigan lobe, Saginaw bay lobe, Huron-Erie lobe, etc. Probably the lobes were coalesced to a great extent when the ice was at its maximum, but they became very prominent in the waning stage and were presumably so also in the advancing stage or earlier part of the life of the ice sheet. Because of this lobation the moraines which were produced in the waning stage are looped around the basins and form sharp re-entrants between them. At these re-entrants a morainic belt is often projected some distance back from the point of junction, forming an interlobate moraine. This feature is well illustrated in northern Alcona county, as indicated below.

Moraines and Ice Borders in Alcona County.—Alcona county stands on the north side of the Saginaw bay ice lobe, for that lobe not only filled Saginaw bay but extended over a wide area on the north, west and south. Several moraines which are distinct ridges at the southwest end of the lobe become merged on its northwest side into a single great morainic system, which bears northeastward from Clare county across the southeast part of Roscommon, the central part of Ogemaw, and southeast part of Oscoda into Alcona county. The ice movement was probably about at right angles to the trend of this morainic system, or northwestward from the central line or axis of Saginaw bay.

Upon crossing the Au Sable river in southwestern Alcona county, this morainic system makes a sharp turn to the northwest and constitutes the divide between the Au Sable and Thunder Bay river drainage in Oscoda and Montmorency counties, thus passing beyond the limits of the Saginaw bay lobe. But from this sharp turn an interlobate moraine, or perhaps it may more properly be termed a morainic spur, extends eastward across the north half of Alcona and the south edge of Alpena county almost to the shore of Lake Huron. The ice appears to have been present on both sides of this spur while it was forming. That on the south was the Saginaw bay lobe, while that on the north may for the present be termed the Thunder bay lobe. Probably this spur was extended eastward with the withdrawal of the ice from the great morainic system toward the Lake Huron basin, and the greater part of it may have been formed during this withdrawal.

Between this great morainic system and the shore of Lake Huron there is, aside from the complicated spur just mentioned, but one well-defined moraine in Alcona county. This has been called by F. B. Taylor the Alcona moraine.[1] In the northern part of the county it is wrapped around the end of the morainic spur, but upon crossing Black river near the line of Alcona and Haynes townships a short distance west of Alcona postoffice, it becomes a separate or distinct ridge and leads southward across Haynes and Harrisville townships, with its eastern or inner border less than a mile from the shore of Lake Huron. Upon entering Greenbush township (T. 25, R. 9 E.) it bears away from the lake shore across Secs. 3, 9 and 17. It is ill-defined from Sec. 17, R. 9, to Sec. 26, R. 8, a distance of 2.5 miles, but has considerable strength in Secs. 26 and 35, R. 8, and enters Iosco county from the latter section. The moraine ranges in width from one-fourth of a mile up to nearly two miles, and rises from 25 to fully 100 feet above border tracts.

There are features in southern Alcona county west of the Alcona moraine that suggest an earlier ice border. Near the western edge of T. 25, R. 8 W. a sand plain sets in which rises about 100 feet above the country east of it with a rather steep ascent. The lower country to the east presents the ordinary topography of a ground moraine, and has drift of variable constitution such as would be expected in deposits made under the ice. The high sand plain is similar to the outwash deposits made by streams issuing from the ice. The only feature needed to make it certain of being an ice border is a terminal moraine, but this feature is wanting or at least is very obscure. It is, however, not uncommon in Michigan to find places where the outwash deposits stand somewhat higher than the moraine and it often happens that in passing from them through the moraine to the inner border district a great descent is made. This is conspicuously the case with the strong morainic system above outlined through much of its course from Clare to Alcona county. It is also not rare to find the terminal moraine becoming very weak while the outwash deposits continue prominent. In view of these conditions it may not be remarkable to find places such as this in southern Alcona county where the ice failed to build up a deposit beneath its edge that would resemble a moraine or approach in bulk that made by the waters in the outer border district. This bluff-like border is more conspicuous near the county line than farther north and becomes a gradual and inconspicuous slope at the north border of the sand plain in Sec. 2, T. 25, R. 7 E. As yet nothing has been noted by which the ice border can be traced farther north. It seems probable, however, that the ice held this position at a time not long previous to that in which it was forming the Alcona moraine. The continuation of the ice border in that case is likely to have been northeastward across Gustin township (T. 26, R. 8 E.) toward the east end of the great interlobate morainic tract of the north half of the county.

The outer border drainage.—The streams which issued from the ice margin during the development of the great morainic system above mentioned, found at first a southwestward discharge to the Muskegon river through the sand plains and swamps of Oscoda, Crawford, Ogemaw and Roscommon counties. But when the ice had shrunk to the inner border of that morainic system lines of discharge were opened along or near that border and the waters reached a lake known as Lake Saginaw in the western end of the low country bordering Saginaw Bay, instead of discharging through the Muskegon to the Lake Michigan basin. This lake, however, had a westward discharge through the Grand river valley into the Lake Mich-

[1] *Moraines of Recession*: Journal of Geology, Vol. V, 1897, pp. 421-465, especially p. 459. *Great ice dams of Lakes* Maumee, Whittlesey and Warren: American Geologist Vol. XXIV, 1899, pp. 6-28, especially p. 20.

igan basin and thence on past Chicago to the Illinois and Mississippi rivers. One of these lines of southwestward discharge had its head on the flat topped gravel tablelands near Bamfield and after following the Au Sable southward about to the line of Alcona and Iosco counties it took a southwestward course to Lupton in Ogemaw county through a sand plain and swamp now drained northeastward by the Little Au Sable. From Lupton it passed southward through a sand plain which borders Rifle river to southern Ogemaw county and there, near Greenwood Station, entered Lake Saginaw.

As the ice melted the lines of discharge were shifted to the east. Lake Saginaw (or perhaps its successor, Lake Warren, see discussion of Lake History below) also became expanded with the retreat of the ice and covered wide areas in Iosco and Arenac counties as well as counties farther south and west, its limits being marked by beaches that are as a rule well defined and easy to trace. The lake may have extended into Alcona county at the level of the sand plain in T. 25, Rs. 7 and 8 E but no shore lines were noted north of there above the Algonquin beach. It therefore seems probable that the lake occupancy was very brief if it extended to that region at all.

The great sand plain which, as above noted, covers much of T. 25, R. 7 E. in Alcona county, also covers several townships in Iosco county. It spreads out like a great delta on each side of the Au Sable river from near the point where that stream enters Iosco county, and covers all of T. 24, Rs. 6 and 7 E. and part of R. 8 E. also much of T. 23, Rs. 6 and 7 E. and extends slightly into bordering townships on the south and east. At the east, as noted above, it terminates abruptly as if prevented by the ice sheet from spreading farther. That the western part was built up largely by a stream flowing down the Au Sable toward the ice is indicated by the slope of its surface, the altitude being about 50 feet higher in the north part of T. 24 R. 5 E. than it is in the southeast part of T. 24, R. 6 E., a distance of eight or nine miles down the valley. But there is very little descent between the east side of T. 24, R. 6 E. and the abrupt border about nine miles farther east. The level eastern part by barometer on train from Oscoda is found to be 830 feet above the sea. As above suggested it seems not improbable that this level corresponds to the highest stage of Lake Saginaw (or of its successor, Lake Warren).

There is a terrace along this part of the Au Sable standing about 40 feet lower than the sand plain. It terminates at the east in the abrupt border above noted as if the stream was still prevented by the ice from carrying material farther. This abrupt border at the point where the Au Sable and Northwestern Railroad strikes it is known as Seven Mile Hill and at that point it is the terrace and not the sand plain which is entered, the border of the sand plain being entered by the railroad west of Bisonette. It is thought that this terrace may also stand at a level of Lake Saginaw (or Lake Warren) but one that is correspondingly lower than the one correlated with the sand plain. The full connections have not been worked out in either case.

The glacial drainage connected with the morainic spur that covers the north half of Alcona county is very obscure. The low plains and swamps which occur among the hills and ridges or border the streams have not sufficient altitude to have given to streams that may have occupied them a southward or southwestward discharge into Lake Saginaw, and it is extremely doubtful if many of them represent lines of glacial drainage. A swamp leading south from the head of Sucker creek through Secs. 21, 28 and 33 T. 27, R. 8 E. to the headwaters of one of the tributaries of Pine river has the appearance of being a line of glacial drainage, though a weak one, for the valley it occupies is in places only one-eighth mile in width. It is thought that the large amount of sand and gravel in the hills and ridges of this morainic tract is an indication that the waters had considerable movement within the ice sheet and may have found discharge to a great degree without reaching the ground moraine under the ice. This being the case the valleys and low areas in this morainic spur may only represent places where the drift was too scanty to build up the surface there to a higher level, and may not be due to erosion either by glacial or postglacial streams.

Thickness of the Drift.—That the glacial deposits of Alcona county are of great depth is inferred from the fact that no outcrops of rock are found within the county even in the deepest valleys, and from the fact that rock has been reached only by very deep borings.[1] The valley of the Au Sable river, though about 400 feet below neighboring hills, carries no rock exposures within the limits of this county. Borings at Killmaster reached a level 150 feet below the level of Lake Huron before entering rock. There are wells 80 to 100 feet or more scattered over the older-settled parts of the county, and these all terminate in the drift. However, it is scarcely to be expected that the rock surface is as low throughout the county as at Killmaster, for in neighboring counties both on the north and south it stands in places 50 to 100 feet or more higher than the surface of Lake Huron. It seems to be below lake level in much of the shale areas on the border of the lake, but it is usually above lake level in the sandstone and limestone areas. If, then, as seems probable, the Berea Grit or other hard rock underlies a part of Alcona county, it is to be expected that the rock surface there will rise

[1] There is a bare possibility that rock was struck at 60 feet in Sec. 3, T. 27, R. 9 E., and at 36 feet at Black river, as indicated in the discussion of wells.

toward lake level, but judging from the outcrops in the neighboring counties there is little likelihood that it will reach an altitude much greater than 700 feet above tide. This leaves room for nearly 600 feet of drift in the highest ridges of the western part of the county, and the depth there may be considerably greater. But little more can be said at present concerning the thickness of the drift, as the data are too meager either to indicate the range in depth or the average thickness.

Structure of the Drift.—The structure of the glacial deposits as here discussed involves not only the kind of rock or constitution, but also the mode of arrangement of the materials. The kind of rocks present in the drift of a given locality is a rude index as to the path over which the ice sheet moved, for fragments of rock from nearly every rock formation passed over are to be found in the material thrown down where the ice melted. The mode of arrangement of the materials is an index of the conditions under which the deposition took place. In some cases the dirt and stones from the melting ice were deposited in a current of water that was issuing from the ice margin; in other cases they were dropped in pools of quiet water, while in still others they fell directly on the ground. There seems, also, to have been considerable water action within the ice, by which the materials which it contained were more or less assorted before they left the ice. The conditions in a given part of the ice margin are liable also to have changed from time to time and produced corresponding changes in the structure. Indeed, such changes seem to have been very general, for one seldom finds a uniform deposit from top to bottom of a drift bank of much height.

In the deposits of Alcona county it is found that the rocks of sufficient size to be easily examined are composed very largely of Canadian crystallines, such as granites, quartzites and greenstones, together with a few red jasper conglomerates and other rocks of limited outcrop in Canada, and an occasional piece of native copper. The surface bowlders, especially, are of Canadian rocks, but these rocks also abound at all depths in the drift. It was noted throughout the county that the proportion of Canadian rocks is much greater than in the drift of the central and southern parts of Michigan. With these Canadian rocks there is a liberal supply of Devonian limestones from the Hamilton formation that outcrops along the west shore of Lake Huron from Alpena northward, and that probably forms the bed of the lake for some distance southeast from Alpena. There are also numerous fragments of Devonian shale. Sandstones are rather rare, especially in the northern part of the county, as is to be expected from the very limited occurrence of sandstone ledges to the northeast of this county. There appear to be two or more sandstones represented, but to what horizon or horizons they belong is not yet known. In the southwestern part of the county a few blocks of the Eo-carboniferous gypsum rock were recognized by W. M. Gregory, who is familiar with the outcrops of this rock formation in Iosco and Arenac counties. On a hill north of Vaughn lake, Gregory has found specimens both of Devonian limestone and of Eo-carboniferous gypsum rock. The former, together with the Canadian rocks which also abound in the same hill, indicate a southwestward movement of the ice, while the latter indicates a northwestward movement. The copper indicates a movement east of south. The northwestward

movement is in harmony with the moraines, as above noted, and was evidently the latest one. The movement which transported material southwestward probably took place while the ice sheet was very thick, and its movement was not controlled by the lake basins to such a degree as in its waning stage. The southeastward movement which brought in the copper may have been a still earlier one, and may also have transported the fragments of red sandstone that are present in this county and appear to be from the Lake Superior Potsdam.

The deposits of Alcona county range from well assorted, definitely bedded sand and gravel, through partially assorted and imperfectly bedded or partially commingled drift to a completely commingled deposit of materials of all sizes without assortment or bedding. The elevated parts of the county are as a rule composed of loose-textured material, but this material presents various degrees of assortment and bedding. In the low tracts there is a large amount of close-textured clayey material, but there are also strips of well-assorted sand and gravel traversing the low tracts. Sand and gravel are also found at moderate depths under much of the clay in the southeastern part of the county. The cause for the wide prevalence of assorted material there is not understood, though it seems probable that it was either an outwash from the ice, which was overridden by a fresh ice advance or the bed of an interglacial lake.

As indicated above, the loose texture and partial stratification and assortment of the material in the morainic tracts are thought to be largely due to the action of water within the ice, for had it occurred outside the ice the material could hardly have had its present irregularities of surface. Instead of a moraine there should be a plain of gravel and sand such as that in T. 25, R. 7 E., if the water action had been outside the ice. There are a few small tracts within the elevated morainic area where but little water action seems to have taken place, and in these places there is a somewhat clayey drift. The most extensive one is west of Curran in the south half of T. 27, R. 5 E., but there is nearly as much clayey drift in the elevated northwest half of T. 25, R. 6 E. Among the smaller tracts is one of three or four square miles in the west edge of T. 25, R. 5 E.; another of about the same area in the southwest part of T. 28, R. 5 E., and a third in Secs. 3, 4, 9 and 10, T. 27, R. 6 E. There is also a large amount of close-textured drift in T. 28, R. 8 E., and the northwest part of T. 28, R. 9 E., on ground less elevated than that of the tracts just mentioned.

The details concerning the surface portion of the drift are given below in the discussion of the soils and the wells. Very little is known concerning the lower portion of the drift. In the borings at Killmaster, which are the only ones which are certain to have reached the bottom of the drift, no notes were kept concerning the character of the deposits overlying the rock.

THE LAKE HISTORY.[1]

Predecessors of Lake Algonquin.—As soon as the ice sheet in the Huron-Erie basin had melted back from the rim of higher land which constitutes the continental divide, the waters from the melting ice became ponded between the ice margin and that divide and found discharge across the lowest point on the divide. This point was at Fort Wayne, Indiana, and the line of discharge is known as the Fort Wayne outlet, while the lake, from its occupancy of the Maumee basin, is known as Lake Maumee. Similarly the melting back of the Saginaw ice lobe resulted in a lake in the plain west of Saginaw bay, which is known as Lake Saginaw. This discharged westward past Pewamo, Michigan, into Grand river, and this outlet is known as the Pewamo channel or Grand river outlet. Lake Saginaw, however, did not begin its history so early as Lake Maumee.

After a time sufficiently long for a well-defined beach to be formed on the shore of Lake Maumee, the ice in the Huron-Erie basin became melted back far enough for the waters of that lake to extend to Imlay, Michigan, where there is another place on the divide which was as low as the head of the Fort Wayne outlet. A double line of discharge then followed, and the level of Lake Maumee was lowered a few feet. It remained at the lower level long enough to form a second beach.

By a further recession of the ice, the waters of Lake Maumee reached

[1] The following references will enable the reader to consult the papers and reports which treat of the lake history here so briefly outlined. Papers which treat only of the beaches of the Superior, Michigan and Ontario basins are not here listed, because of the remoteness of application to this region.

Dryer, C. R.—Geology of Allen County, Indiana: Sixteenth Ann. Rept. Geol. Survey Indiana, 1888, pp. 105-114.

The drift of the Wabash-Erie regions: Eighteenth Ann. Rept. Geol. Survey Indiana, 1893, pp. 82-90.

Fairchild, H. L.—Lake Warren shore lines in western New York: Journal of Geology, Univ. of Chicago, Vol. V, 1897, pp. 269-282.

Glacial waters in the "Fingerlakes region": Bulletin Geol. Society of America, Vol. X, 1899, pp. 20-68.

Glacial lakes Newberry, Warren and Dana, in central New York: American Journal of Science, Fourth series, Vol. VII, 1899, pp. 249-263.

Gilbert, G. K.—Surface Geology of the Maumee Valley: American Journal of Science, Third series, Vol. I, 1871, pp. 339-345: Also Geology of Ohio, Vol. I, 1873, pp. 537-556.

History of Niagara River: Sixth Rept. New York State Reservation at Niagara, 1890, pp. 61-84.

Niagara River: National Geographic Monographs, Vol. I, 1896, pp. 203-236.

Modification of the Great Lakes by earth movement: National Geographic Magazine, Vol. VIII, 1897, pp. 233-247. For fuller discussion see Eighteenth Ann. Rept. U. S. Geol. Survey, Part 2, 1898, pp. 601-647.

Hubbard, Bela.—Lake Ridges in Southeastern Michigan: Third Annual Report of State Geologist of Michigan, pp. 102-111. Published separately as H. R. No. 8, Detroit, 1840.

Lane, A. C.—Geological report on Huron county, Michigan: Geological Survey of Michigan, Vol. VII, 1900, Part II, pp. 62-85.

Leverett, Frank.—Correlation of the moraines with the raised beaches of Lake Erie: American Journal of Science, Third Series, Vol. XLIII, 1892, pp. 281-301.

Correlation of New York moraines with raised beaches of Lake Erie: American Journal of Science, Third Series, Vol. L, 1895, pp. 1-20.

Correlation of moraines with beaches on the border of Lake Erie: American Geologist, Vol. XXI, 1898, pp. 195-199.

Glacial Formations of the Erie and Ohio Basins: Monographs of the U. S. Geological Survey, Vol. XLI, 1901, pp. 581-775.

Mudge, E. H.—Drainage Systems of the Carboniferous area of Michigan: American Geologist, Vol. XIV, 1894, pp. 301-308.

Mouth of Grand River: American Journal of Science, Fourth Series, Vol. VIII, 1899, pp. 31-34.

Newberry, J. S.—Lake Ridges: Geology of Ohio, Vol. I, 1873, pp. 178-183; Vol. II, 1874, pp. 50-65.

Read, M. C.—Lake Ridges and Terraces: Geology of Ohio, Vol. I, 1873, pp. 488-492, 516-519.

Sherzer, W. H.—Geological report on Monroe county: Geol. Survey of Michigan, Vol. VII, 1900, pp. 132-144.

Spencer, J. W.—Ancient shores, bowlder pavements and high-level gravel deposits in the region of the Great Lakes: Bulletin Geological Society of America, Vol. I, 1890, pp. 71-86.

Deformation of the Algonquin beach and birth of Lake Huron: American Journal of Science, Third Series, Vol. XLI, 1891, pp. 12-21.

Notes continued on page 52.

the vicinity of Ubly, Michigan, and there found a lower line of westward discharge than the Fort Wayne and Imlay outlets. The lake level was lowered about 30 feet, and the other outlets were abandoned. Because of this change in outlet the lake has been given a different name from its predecessor and is called Lake Whittlesey, in honor of Charles Whittlesey, one of the earliest students of these old beaches. By the time Lake Whittlesey began its history, Lake Saginaw had come into existence, and Lake Whittlesey discharged into it. The Ubly outlet entered Lake Saginaw near Cass City, and from there westward into Saginaw county there was only a narrow strip of water along the south edge of the ice sheet, which then had its southern limits at a moraine that follows the north side of Cass river.

By a farther recession of the ice on the "Thumb" of Michigan, a wide opening was made from Lake Whittlesey to Lake Saginaw at a level as low as Lake Saginaw, and the two lakes became united. Because of this lowering of level and union of the two lakes a new name, Lake Warren, has been applied in honor of G. K. Warren, a pioneer student of lake beaches. Lake Warren discharged through the Grand river outlet down to a time when the ice at the eastern end of the great basin occupied by Lake Erie and Lake Ontario had melted back far enough to permit the discharge of its waters eastward to the Mohawk river. The

---

High level shores in the region of the Great Lakes and their deformation: American Journal of Science, Vol. XLI, 1891, pp. 201-211.
Post-Pliocene subsidence versus glacial dams: Bulletin Geological Society of America, Vol. II, 1891, pp. 465-476.
Deformation of the Lundy beach and birth of Lake Erie: American Journal of Science, Third Series, Vol. XLVII, 1894, pp. 207-212.
The duration of Niagara Falls: American Journal of Science, Vol. XLVIII, 1894, pp. 455-472.
A review of the history of the Great Lakes: American Geologist, Vol. XIV, pp. 289-301.
The geological survey of the Great Lakes: Proceedings American Association for the Advancement of Science, Vol. XLIII, 1895, pp. 237-243.
An account of the researches relating to the Great Lakes: American Geologist, Vol. XXI, 1898 pp. 110-123, 393-396.
Another episode in the history of Niagara Falls: American Journal of Science, Fourth Series, Vol. XVI, 1898, pp. 439-450.

Taylor, F. B.—The highest old shore line on Mackinac Island: American Journal of Science, Vol. XLIII, 1892, pp. 210-218.
The ancient strait at Nipissing: Bulletin Geological Society of America, Vol. V, 1893, pp. 620-626.
The limit of postglacial submergence in the highlands east of Georgian Bay: American Geologist, Vol. XIV, 1894, pp. 273-289.
The Munuscong Islands: American Geologist, Vol. XV, 1895, pp. 24-33.
The second Lake Algonquin: American Geologist, Vol. XV, 1895, pp. 100-120, 162-179.
Changes of level in the region of the Great Lakes: American Journal of Science, Third Series, Vol. XLIX, 1895, pp. 69-71. Also Niagara and the Great Lakes: pp. 249-270.
Preliminary notes on studies of the Great Lakes made in 1895: American Geologist, Vol. XVII, 1896, pp. 253-257.
Correlation of Erie-Huron beaches with outlets and moraines in southeastern Michigan: Bulletin Geological Society of America, Vol. VIII, 1897, pp. 31-58.
Origin of the gorge at the whirlpool rapids at Niagara: Bulletin Geological Society of America, Vol. IX, 1898, pp. 59-84.
The great ice dams of Lakes Maumee, Whittlesey and Warren: American Geologist, Vol. XXIV, 1899, pp. 6-38.
A short history of the Great Lakes: Dryer's "Studies in Indiana Geography," Inland Publishing Co., Terre Haute, 1897, pp. 90-110.

Upham, Warren.—Relationship of the glacial lakes Warren, Algonquin, Iroquois and Hudson-Champlain: Bulletin Geological Society of America, Vol. III, 1892, pp. 484-487.
Late glacial or Champlain subsidence and reelevation of the St. Lawrence River Basin: American Journal of Science, Third Series, Vol. XLIX, 1895, pp. 1-18.
Stages of recession of the North American ice sheet shown by glacial lakes: Bulletin Geological Society of America, Vol. VI, 1895, pp. 21-27.
Beach ridges in Cleveland: Bulletin Geological Society of America, Vol. VII, 1896, pp. 340-348.
Origin and age of the Laurentian lakes and of Niagara Falls: American Geologist, Vol. XVIII, 1896, pp. 169-177.

Whittlesey, Charles.—On the natural terraces and ridges of the country bordering Lake Erie: American Journal of Science, Second Series, Vol. X, 1850, pp. 31-39.

Winchell, N. H.—The surface geology of northwestern Ohio: Proceedings American Association for the advancement of Science, Vol. XXI, 1872, pp. 152-186.

Wright, A. A.—Map of lake ridges in Lorain and Cuyahoga counties: Geology of Ohio, Vol. II, 1874, pp. 58-59.

lake then ceased to exist as a single large body, but was succeeded by three lakes: Lake Algonquin, which occupied much of the area of Lakes Superior, Michigan and Huron, and the low land on their borders; Lake Erie, in the Erie basin, and Lake Iroquois, in the Ontario basin. It is only with the first of these lakes that we are here concerned.

Lake Algonquin.—The name Lake Algonquin was applied by J. W. Spencer in 1888 to a body of water which occupied the basins of the upper Great Lakes and discharged through the Trent valley in Ontario into Lake Iroquois in the Ontario basin.[1]

The shore or beach of this lake was first discussed by Spencer in 1891, attention being called chiefly to the part of its shore southeast of Lake Huron and Georgian Bay.[2] The presence of the beach on the west shore of Lake Huron was inferred but not observed by him. The tracing of the part of this beach in Michigan has been done by F. B. Taylor, who in 1895 carried his studies from the Straits of Mackinac southward on the shore of Lake Huron and of Lake Michigan far enough to determine the extent of Lake Algonquin in each of these basins. He has also extended his studies some distance into the Lake Superior basin. The results of his work have only been briefly outlined in a communication to the American Geologist in 1896[3] and in his "Short History of the Great Lakes" in 1897[4]. He found that Lake Algonquin had at first a southward discharge through the St. Clair and Detroit rivers into the Erie basin, for it came into action before the ice had withdrawn from Balsam Lake at the head of the Trent valley in Ontario. When the ice uncovered Balsam Lake the discharge of Lake Algonquin shifted to the Trent valley. It is his opinion that the head of the Trent outlet was not much below the level of the St. Clair outlet at that time so that the change produced but a slight lowering of the lake. He has also found that Lake Algonquin had its discharge shifted back to the St. Clair outlet through an uplift of the region occupied by the Trent outlet. His history has, therefore, been more complex than was anticipated by Spencer.

These investigations by Spencer, Taylor and others have shown that the Algonquin beach on the borders of Lake Huron and Lake Michigan is inclined upward in a north-northeast direction, but that in the eastern half of the Superior basin it is practically horizontal. It was of course horizontal throughout when formed except perhaps at its northeast end on the immediate border of the ice sheet where ice attraction may have held the water a little higher than the general level of the lake. The departure from horizontality here in Michigan may, therefore, be taken as a measure of the amount of uplift that has occurred. The level of the Algonquin beach at the south end of Lake Huron as interpreted by Taylor, is about 25 feet above the surface of Lake Huron. The rise is very gradual between there and Alcona county for the beach at Greenbush Station on the new line of the Detroit and Mackinaw railroad is about 60 feet and at the court house at Harrisville 63 feet above Lake Huron (as determined by hand level from railway track on Main street in Harrisville). But on Mackinac Island the beach is 170 to 205 feet above Lake Huron. Taylor reports that there is a heavy well-developed beach at an altitude about 170 feet which is the lowest of a series of four or five similar ridges which rise by successive steps to an altitude of about 205 feet above Lake Huron.[5]

According to Spencer the Algonquin beach rises on the east shore of Lake Huron from 18 feet below Lake Huron at Port Huron to 134 feet above the lake at Southampton, Ontario, which is nearly opposite Greenbush in Alcona county. This part of the east shore is nearly along the line of uplift while the west shore departs from it 45 to 60 degrees or more. It is, therefore, not surprising that the beach stands markedly higher at Southampton than at Greenbush.[6] The rise from Port Huron to Southampton, allowing it to be 25 feet above Lake Huron at Port Huron, is about one foot per mile, while from Port Huron to Greenbush it is about 3.5 inches per mile.

The Algonquin beach is a strong one in Alcona county and has been recognized by many of the residents as an old lake shore. It has been cut back in places about one-fourth of a mile into the slope of the Alcona moraine, and presents in such places a steep bluff, which may be 30 to 50 feet in height. The average height from Greenbush northward to the north line of the county is more than 20 feet. South from Greenbush the lake did but little cutting. Instead it built a series of low gravelly bars 3 to 6 feet high and 50 to 100 yards or more wide, which are separated by narrow swamps or sloughs. These fill in much of the interval between the Alcona moraine and Cedar lake.

In front of the old lake bluff bowlders are in places so numerous as

[1] Proceedings American Association for Advancement of Science, Vol. 37, 1888, p. 199.
[2] Deformation of the Algonquin beach and birth of Lake Huron: American Journal of Science, Vol. 41, 1891, pp. 11-21.
[3] Preliminary notes on studies of the Great Lakes made in 1895: American Geologist, Vol. 17, 1896, pp. 253-257.
[4] Dryer's "Studies in Indiana Geography," pp. 102-105.
[5] The highest old shore line on Mackinac Island: American Journal of Science, Vol. 43, 1892, p. 210.
[6] American Journal of Science, Vol. 41, 1891, p. 14.

to constitute a pavement. They abound for a distance of one-fourth to one-half mile east from the old shore. They are probably in large part a residue from the glacial deposits which the lake eroded as it was cutting back its shore, but some may have been shoved up toward the shore by rafts of ice in the spring. There are also deposits of cobble and gravel along the base of the lake bluff at numerous points. In the village of Harrisville the gravel stands in a double crested ridge or bar with a swamp back of it and a rather steep bank along the front. The court house is built on the front or eastern crest. It is probable that the bar is a storm beach and stands slightly above the mean level of the old lake. This may account for the cutting of a bank on its front. In this connection it may be remarked that the base of the bluff is generally a few feet lower (5 to 10 feet) than the highest part of the gravel bars along the old shore. This is perhaps an indication that the lake had dropped to a slightly lower level before it had completed the cutting of the bluff. The solution of the question should be reached as studies become more extended.

The Nipissing Great Lakes.—When the ice sheet had melted away from the lower end of the St. Lawrence valley a direct eastward outlet for the three lake basins which had been occupied by Lake Algonquin was opened, and the waters fell nearly to the level of the present lakes. They were connected by straits almost as narrow as at present, and hence may be considered independent water bodies. Taylor has given them the name Nipissing Great Lakes, from the Nipissing outlet or pass through which the waters discharged from the east end of Georgian bay into the Mattawa-Ottawa channel that led to the St. Lawrence. The lakes which we have been considering were glacial lakes whose extent and altitude were more or less dependent upon the ice sheet, but the Nipissing Great Lakes were post-glacial and independent of the ice sheet.

The Nipissing beach formed on the west shore of Lake Huron was found by Taylor to intersect the shore of Lake Huron near Harrisville. To the south from there it is below the surface of Lake Huron, while to the north it rises gradually, reaching an altitude of about 45 feet above the lake at Mackinac Island and about 100 feet at the Nipissing outlet at the east end of Georgian bay. The city of Alpena is built on this beach, and it forms a conspicuous sandy belt in the northeast part of Alcona county along the east side of the north fork of Black river. It comes to the shore of Lake Huron about a mile south of Black River village, and is not well displayed farther south except perhaps in the low sandy ridges at and back of Sturgeon Point light-house. These were probably formed by Lake Nipissing rather than by Lake Huron, though they stand so near the level of the high stages of Lake Huron that it is not an easy matter to settle their relationship to Lake Nipissing.

The strength of the Nipissing beach and the size of its outlet channel indicate that the lake lasted through a considerable period. Taylor thinks that its beach is stronger than the Algonquin. Its history was brought to a close by the shifting of the outlet to the present one, through the St. Clair river, as a result of the uplift of the northern part of the country.

Lake Huron.—The fluctuations of Lake Huron, the probable length of time it has existed, and the various phases of its shore, have been

discussed at some length by State Geologist A. C. Lane in his report on Huron county in Vol. VII of this survey. It is his opinion that the work accomplished by the Nipissing lake and Lake Huron, which he thinks have a level very nearly coincident in that county, is greater than that by Lake Algonquin in about the ratio of 3 to 2, and that the work accomplished since the beginning of Lake Algonquin is somewhat greater than that by Lakes Whittlesey and Warren. The records of lake fluctuation for the 100 years 1800 to 1899, together with the rainfall data from 1857 to 1899, are set forth graphically in a diagram. It appears that there is a rude correspondence between the extreme stages of the lake and the wet and dry periods, as well as an annual cycle dependent upon the rainfall, evaporation, etc., at the various seasons of the year. The extreme fluctuation is nearly 6 feet and the annual about 1.34 feet.

Aside from the fluctuations which are due to variations in rainfall, there is thought to be a gradual emergence of the land on the border of Lake Huron as the result of an uplift now in progress. This matter has been investigated by G. K. Gilbert of the United States Geological Survey, and he calculates that the rise of land at the Straits of Mackinac is at the rate of 6 inches per century, and diminishes to zero between there and the outlet at Port Huron.[1] Concerning the length of time Lake Huron has existed, Gilbert remarks as follows:[2]

"The deduced mean rate of change—0.42 foot to the 100 miles in a century—depends on assumptions which are convenient rather than probable. These are: (1) that the whole region moves together as a unit being tilted without internal warping, and (2) that the direction of its present tilting is identical with the direction of the total change since the epoch of the Nipissing outlet of the upper lakes. What we know of the general character of earth movements gives no warrant of such assumptions of uniformity, but no better assumptions as to this region are now available. * * * * * I am disposed to ascribe only a low order of precision to the deduced rate of change, and regard it as indicating the order of magnitude rather than the actual magnitude of the differential movement.

"If we assume that the rate of 0.42 foot per 100 miles per century is uniform and secular, and project it backward to the time when the drainage of Lake Huron was shifted from North Bay to Port Huron, we obtain for the period since that change about 10,000 years. From studies at Niagara, Taylor has estimated the same period as between 5,000 and 10,000 years; (Bull. Geol. Soc. America, Vol. IX, 1898, p. 83) and the comparison indicates that the rate of modern change is of such magnitude as to accord well with the idea that it continues the geologic change."

In the last 16 years the land is said to have made 10 rods abreast of the life saving station at Sturgeon Point. At the beginning of the period it was cutting right up to the fence lines of the light-house enclosure. Thence all the way to Harrisville there seems to be a strip 200 feet wide of recent growth, and at Harrisville the report is that from 1884 to 1886 the lake was cutting the bluffs, which are now about 330 feet from the lake front.

ECONOMIC RESOURCES.

Soils.—Alcona county presents wide variations in the character of its soil, there being a range from the most productive clay and clay-loam soils to the most barren sand. There is also considerable swampy land with peaty soil. The clay and clay-loam soils usually contain enough water to supply the needs of plants. The sandy and loose-textured soils vary greatly in the moisture contained in them, in some cases being sufficiently damp to be productive, and in some cases dry and barren. The following classes of soil may be readily distinguished: 1, clay; 2, clay-loam; 3, sandy loam; 4, wet sand; 5, dry sand; 6, peaty or organic

[1] Eighteenth Annual Report U. S. Geological Survey, part 2, pp. 630-640.
[2] Loc. cit. pp. 637-639.

soil. There are parts of the county where a single class of soil prevails over a wide area, and parts where a single farm may contain two or more classes. In the latter case the soil is referred to as mixed or variable. The descriptions of the soil below are given by townships, beginning at the lowest number and working to the highest, and should be used to supplement the map, Plate II.

In T. 25, R. 5 E., situated in the southwest corner of the county, there is a strip of productive land with clay-loam soil occupying the west border in Secs. 7, 17, 18, 19, 20, 30 and 31. There is also clay-loam on the east border in Secs. 1, 24 and 25. The remainder of the township is mainly sandy barrens, the principal exception being a narrow strip of wet land along the Au Sable river valley.

In T. 25, R. 6 E., there is a tract of productive clay and clay-loam soil embracing fully 25 square miles. The poor land lies around the edge of the township, there being a narrow strip on the south edge that is sandy, and parts of the north and west borders that have a sandy loam of poor quality and too broken for easy cultivation. A portion of the productive land in the north and west parts of the township has a very hummocky topography, and is therefore difficult to cultivate, but makes excellent pasture land. Several lakes in this broken area add to its value for pasture or grazing.

In T. 25, R. 7 E., there is only a narrow strip of productive land situated on the north and west borders, mainly in Secs. 1, 4, 5, 6, 7, 18 and 19, and embracing perhaps 6 square miles. It has a mixed soil with spots of clay, with wider areas of sand and sandy loam. The remaining parts of the township are dry, sandy barrens.

In T. 25, R. 8 E., there is a large amount of wet land mapped by the land survey as swamp, but which when cleared and ditched is found to be a good farming district. In the northeast part of the township in Secs. 1, 2, 11, 12, 13 and 14, there is a heavy clay soil. The remainder of the township carries a mixed soil with abrupt changes from sand to clay and a predominance of sand. With the exception of a narrow strip of dry sand on the west border, which is barren, the sand of this township is generally productive, and several good farms have already been cleared in the central part of the township.

In T. 25, R. 9 E., there is a heavy clay soil in Secs. 5, 6, 7 and 18, and considerable productive land from these sections eastward to the shore of Lake Huron. A part of the moraine in Secs. 4, 8 and 9 has a rather light sandy loam soil. The south half of the township is largely swamp land interspersed with sandy and gravelly ridges formed by Lake Algonquin. Some of the wet land in the southwest part of the township has been brought under cultivation and proves to be very productive. It embraces a bay of Lake Algonquin and has a soil of fine sand or loam.

In T. 26, R. 5 E., there is a very broken tract of sandy loam. The same is true of T. 26, R. 6 E., except about 12 square miles in the northeast part, which is a level tract of wet sand. Both townships are much better adapted to grazing than to farming. There are several lakes in the hilly portion and several small streams in the flat portion, which afford an abundant supply of water for herds.

In T. 26, R. 7 E., there are a few square miles of sand and sandy loam with rather light soil, but much of the township has a productive soil of clay and clay-loam. The most barren soil is found in Secs. 18, 19, 20,

21, 22, 27 and 28, being largely dry sand. Secs. 1, 2, 3, 4, 12 and 13 have much sandy land but are well watered and adapted to grazing. The remainder of the township has a mixed soil with patches of clay and much clay loam and a moderate amount of sandy loam. Nearly all can be brought under cultivation except the sandy sections above mentioned.

In T. 26, R. 8 E., there is a tract of productive clay land in the eastern part, in Secs. 11, 13, 14, 23, 24, 25, 26, 35 and 36. The northern third has a sandy loam and is adapted to grazing rather than agriculture. The remainder of the township has a mixed soil with a sufficient amount of clay and clay-loam to justify bringing it under cultivation, and a large part is already cleared and farmed.

The greater part of T. 26, R. 9 E., is productive farming land. There are a few farms with sand and sandy loam along the Alcona moraine in the eastern part of the township. The northwest part in Secs. 5, 6, 7, 8, 17 and 18 also has a sandy loam soil, but it is fair to good farming land. The narrow lake plain is in places very stony and is on the whole less productive than the upland back of it.

In the southeast part of T. 27, R. 5 E., there is a tract of about 15 square miles which has a productive soil of clay and clay-loam. The western and northern portions have a lighter soil, adapted to grazing rather than farming. The northeast part is level, and there is considerable swampy land in Secs. 1, 12 and 13.

In T. 27, R. 6 E., there is a tract with productive clay-loam soil extending northeast from the productive tract in T. 27, R. 5 E., from Secs. 18, 19, 30 and 31 to Secs. 3 and 4. It is very hilly in Secs. 17, 18, 19, 20, 30 and 31, and difficult to cultivate, but in Secs. 3, 4, 9 and 10 there is an undulating surface easy to farm. The remainder of the township is adapted to grazing and well watered, but the soil is rather light for farming.

In T. 27, R. 7 E., there is very little productive farming land. The northwest quarter is largely swamp and part of it covered continually with water. It opens into Hubbard lake at the northeast end. The remainder of the township has a rather light sandy loam soil that can be best utilized for grazing land.

In T. 27, R. 8 E., the productive land is largely situated in the southeast quarter, there being considerable clay-loam soil in Secs. 23, 24, 25, 26, 27, 34, 35 and 36. There is a swampy tract along Sucker creek, which when cleared up and ditched may become productive. The uplands in the northern and western parts have some clay-loam, but sandy soil predominates and grazing would probably be more profitable than agriculture.

In T. 27, R. 9 E., there is a large amount of productive farming land, which is nearly all under cultivation. The western and northern borders have a sandy loam, and the moraine and lake plain that lie between Black river and Lake Huron have a sandy or sandy loam soil, but in the remainder of the township clay-loam greatly predominates over the lighter soils.

In T. 28, R. 5 E., in the extreme northwest part of the county, there is but little land adapted to agriculture, and this is in a belt of hardwood timber in the southwest part, covering parts of Secs. 29, 30, 31, 32, 33 and 34. The eastern edge of the township is flat and rather wet. The remainder is dry and largely rolling land with light soil.

On the west border of T. 28, R. 6 E., there is a strip of flat and rather wet sandy land. There is also a large swamp in the northeast part in Secs. 1, 2, 3, 11 and 12. The remainder of the township is rolling land with rather thin soil. The wet land may be brought under cultivation after it is cleared up and ditched, but the uplands are scarcely suitable for farming.

In T. 28, R. 7 E., there is scarcely any land under cultivation and much of it has a light soil. Hubbard lake occupies about one-third of the township. It is doubtful if the uplands west of the lake will be worth settling, but northeast of the lake the soil is better, though it is a very hilly tract.

In T. 28, R. 8 E., there is a large amount of productive land. At least 80 per cent of the land is a rich clay or clay-loam. The only tracts worth mentioning that are too light for agriculture are small areas in the northeast and southeast corners and in Secs. 21 and 28. There is a large swampy tract at the headwaters of Sucker creek in Secs. 25, 26, 27, 34 and 35. There are also swamps in the southwest and northwest parts of the township.

In T. 28, R. 9 E., which is the northeastern corner township, there are a few square miles of productive land in Secs. 6, 7, 8, 17, 18, 19, 20, 21 and 22, with considerable clay-loam soil. There is a very broken tract south of these sections in the southwest part of the township with a rather light soil. The remainder of the township is a low swampy tract bordering the lake.

Wells.—It is only in the thickly settled eastern portion of the county that wells have been put down in sufficient number to test the supply of underground water, and even there it has usually been tested only to very slight depths. Throughout the thinly settled western and central portions, springs and surface water are generally adequate to the needs of the residents, though the quality of water is in some cases very poor.

The wells are usually between 15 and 30 feet in depth and obtain a moderate supply of water of fair quality. They appear to be supplied largely by seepage from the clay which prevails in that part of the county. The deep wells present less uniformity than the shallow ones, some being strong while others are so weak as to be pronounced failures. Some are entirely through clay, while others are largely through sand, and still others pass through alternations of sand and gravel with clay. The wells indicate that there is a widespread and thick bed of sand under the surface clay in the eastern part of the county. It is often dry for a few feet, but is charged with water farther down. In such wells there is little or no rise of the water above the level at which it was struck. Wells which enter water-bearing sand immediately under the clay are liable to have a head considerably higher than the top of the sand bed.

It is probable that flowing wells may be obtained by sinking to a depth of 100 to 150 feet or less in several localities within the county, for the situation is very similar to that in flowing-well districts in neighboring counties toward the southwest. The eastern slope of the prominent moraine from Lott postoffice northward across Tps. 25, 26 and 27, R. 6 E., seems a very favorable place for flowing wells, the conditions being similar to those at Rose City and West Branch, in Ogemaw county. Possibly flows may be obtained in the southeast part of T.

27, R. 5 E., and northwestward from there past McCollum lake. If the ice sheet pushed up into that region from the northeast, as seems probable, the waters which soak in along the elevated moraine that constitutes the divide between the Au Sable and Thunder Bay rivers are likely to be working down the slope toward Thunder Bay river and may have sufficient head to overflow in the comparatively low tracts at the head of Wolf, Silver and McGinn creeks, and for some distance down these streams.

In the eastern part of the county, flowing well prospects seem good all along the lake shore on the east side of the Alcona moraine. Flows may also be struck in low ground both north and south of the divide between tributaries of Hubbard lake and the headwaters of the east and west branches of Pine river. One flowing well has already been obtained near a branch of Pine river in Sec. 11, T. 26, R. 8 E., at the moderate depth of 65 feet, which is at least an encouragement to prospect for others in similar situations along each side of this divide.

At Harrisville and Springport and for some distance north and south from these villages there are strong springs issuing along the border of the lake, which supply the needs of residents to such an extent that but few wells have been made.

At Black River village water is hauled from the lake and delivered in barrels to the residents, the lake water being of far better quality than that obtained in shallow wells in that swampy tract. W. R. Smith made a boring in this village which struck a hard material, possibly bed rock, at 36 feet. A second boring a few feet distant struck a similar material at the same depth.

At Greenbush wells 25 to 30 feet deep furnish a good quality of water. They are largely through sand and gravel.

In the vicinity of Lincoln the wells are 30 to 40 feet in depth, largely through sand. In this village the lakes are used to a great extent for watering horses and cattle.

In and near Mikado several wells are about 30 feet in depth, and are largely through clay. William Dolson has a well 64 feet deep on his farm south of the village which was all clay except thin sand beds at 45 and 50 feet. It was of a yellow color to a depth of 12 feet, the remainder blue. There is a good supply of water in this well, but one 20 rods south at John Butterfield's reached a depth of 70 feet without obtaining a supply of water.

At Killmaster there is abundance of water at various depths, as shown by the three deep borings made in prospecting for oil. The water overflows from the base of the drift. Records of the borings appear in Dr. Lane's discussion of gas (pages 65 to 67 of this report).

At Vaughn Station, Hartwell Hayes bored 80 feet through clay and found very little water, but several wells in the vicinity of this station obtain a good supply of water at about 30 feet.

The following records of farm wells in the eastern part of the county illustrate the variable depths at which water is found, and to some extent the beds penetrated:

A boring in Sec. 4, Greenbush township on land of James McClelland was sunk 95 feet entirely through sand and gravel without obtaining water. It is on the crest of the Alcona moraine at an altitude about 160 feet above Lake Huron.

John R. McDonald has a well in Sec. 6, Greenbush township, 44 feet deep, which passed

through a blue-black clay in its lower part but obtained a good quality of water. Some wells in that vicinity have a water with a bad odor, obtained in the blue-black clay.

A. D. McDonald has a well in Sec. 9, Greenbush township, 44 feet deep, which has only two feet of water, but is a strong well. It penetrated 14 feet of clay at top, below which was dry sand to the water near bottom of well. Mr. McDonald has dug a number of wells in that vicinity on other farms which enter sand below a few feet of clay.

Adolphus Lovlett in Sec. 34, Harrisville township, bored 60 feet without obtaining water, but a well across the road obtained water at 30 feet. It is, however, of poor quality with offensive oder.

Charles Clayton has a well in the northwest part of Sec. 34, which obtained a good supply of water. The depth is 57 feet; for 40 feet there is a loose textured material below which is a hard clay.

Mrs. Dean made a boring 105 feet at her residence in Sec. 22, Harrisville township, which struck a water-bearing fine sand at 45 feet and did not reach the bottom of that deposit The pipe has been drawn up to the top of the sand bed because the sand screens better there than in the lower part.

James Clemens bored 110 feet at his residence in Sec. 20, Harrisville township,* and obtained but little water. There are, however, several good wells near by with a depth of only 20 to 30 feet.

Frank Spencer has a well in Sec. 18, Harrisville township, 66 feet deep that has 40 feet of water. It penetrated 47 feet of dry sand, and then wet sand to the bottom.

Mrs. Chapel, 2.5 miles west of Harrisville, has a well 95 feet, but wells in that vicinity are usually shallow.

Thomas Stone has a well in Sec. 15, Harrisville township, 56 feet deep, which struck a weak vein of water in fine sand near the bottom.

Mrs. B. Culver's well about a mile southeast of Lincoln is 68 feet deep and water rises 17 feet.

The flowing well at Frank Blong's residence, two miles southwest of Lincoln, in Sec. 11, T. 27, R. 8 E., is 65 feet, with the head five feet above the surface. It penetrated: (1) clay 18 feet; (2) gravel and weak water vein, 8 inches; (3) clay with hard crust at about 30 to 35 feet from surface and softer clay below, 44 feet; (4) gravel with flow of water, 2 feet. Altitude of well about 120 feet above Lake Huron.

John Clarke, in Sec. 27, T. 27, R. 8 E. has a well on high ground that is 65 feet deep and has very little head, though a strong well. It penetrated: (1) loamy soil 3 or 4 feet; (2) yellowish clay 30 feet; (3) dry sand, becoming wet near bottom, 30 feet. Mr. Clarke made a well on low ground in the northwest part of this section which has some oil on the water and an offensive smell when boiled.

Arthur Close has a well 53 feet deep in Sec. 34, T. 27, R. 8 E. that has only a few inches depth of water yet is strong. Edward Burge has another in the same section, 40 feet deep, with but little head, and D. W Brooks has one in Sec. 36, that is 36 feet in depth. In this well there are 24 feet of stiff clay below which are thin beds of sand and clay.

Napoleon Sherbeneau made a well 117 feet deep in Sec. 34, Haynes township, which is in sand and gravel at bottom, but passed through much clay. It has considerable head. His neighbor, James Barber, in the same section has a well 104 feet which also has considerable head. Another neighbor, Mr. McIntyre, in Sec. 4, Harrisville township, has a good well 56 feet deep. Each well is about 170 feet above Lake Huron.

Frank Elmer, near center of Sec. 3, Haynes township, sunk a well 64 feet, 2 in. deep, which is reported to have entered a white material near the bottom that contains some mineral thought to be lead. The beds passed through are said to be: 20 feet clay, 4 feet sand where first well caved, 3 feet boulders, 4 feet blue clay hardpan, 10 feet quicksand, then hardpan and sticky stuff to the water gravel. The water is hard, but free from chlorine or sulphates. Mr. Leverett was told that the well went through 40 feet clay and 20 feet gravel before striking the white material. Other deep wells in the north part of Haynes township are as follows: James Martin's, east side of Sec. 10, depth 104 feet; Joseph Miller's in southwest part of Sec. 11, about 80 feet; Fred Otto's, in southeast part of Sec. 5, 56 feet. None of these wells struck the white material which was found in Mr. Elmer's well.

Alexander McDonald's well, in the southeast part of Sec. 2, T. 28, R. 8 E. is 103 feet. It penetrated 20 feet of clay at the top, below which was dry sand, becoming wet near bottom. The altitude is about 280 feet above Lake Huron. A neighboring well in Sec. 11, is 80 feet. West from there on the low tract near Spruce postoffice wells are obtained at shallow depths.

MARL.—LEVERETT.

Marl deposits in Alcona county, so far as examined, were found to be too thin to be utilized in the cement industry. There is from 6 to 10 feet of rather impure marl in the lake on the township line a mile west of Lincoln. About 6 feet of marl, apparently of good quality, was found on the border of Tubb's lake in Sec. 31, T. 26, R. 7 E., forming a platform 10 or 12 rods wide. Marl deposits 1.5 to 2 feet thick are exposed in a railway ditch in a swamp one-half mile north of Harrisville Station, and a similar depth in railroad ditches south of Greenbush on the west side of Cedar lake.

* Near the east branch of the Pine, 640 A. T.

MARL (BOG LIME).—LANE.

Deposits of what is popularly known in Michigan as marl, but is nearly a pure calcium carbonate, occur at a number of points at Springport (South Harrisville), Kirk Ludington's, Shabno's, four miles south of the Presbyterian church in T. 27 N., R. 9 E., etc.

A very interesting deposit in some ways is one that is crossing the lake road about three miles and a half north of Harrisville. It covers probably not less than 20 acres. I do not know how deep it is, though it has been tested. The interesting thing, however, is its mode of occurrence, which is directly in front of the bluffs worn by the lake at a higher level, with no ridge or barrier between it and the present lake. It is wasting away, but the upper part is redissolved and precipitated and passes into a firm and hard calcareous tufa, while as one goes down it becomes granular and then soft. It appears to be a genuine Chara lime formed by the precipitation of lime by the lake weed known as Chara, but it can hardly be supposed to have been found in such purity directly on the beach of a great lake, and we are forced to assume that it is the relic of a small lake, the rest of which has been eroded away.

There is enough, perhaps, for lime kilns, but hardly, I think, for a cement plant; and, beside, it is so hard and granular on top that the advantage of marl, its fine sludgy character suitable for mixing, would be lost.

CLAY.—LEVERETT.

In general, clay deposits of fine and uniform texture are rather rare in Alcona county, but in the southeast part there is considerable clay that carries but few pebbles, an area of several square miles being found around Mikado and northward from there between Gustin and Killmaster. Although an unsuccessful attempt has been made to burn a kiln of brick at Mikado, it seems probable that the surface clay will in many cases prove suitable for brick or tile. It will at least be worth while to experiment further with the clay, for that part of the county would be greatly improved by underdraining with tile, and it will be an advantage to manufacture the tile where it is to be used.

CLAY.—LANE.

At South Harrisville, Sec. 32, T. 26 N., R. 9 E., some brick has been made of glacial clay. It is not entirely free from pebbles, effervesces somewhat and makes cream-colored brick. Some brick has been made also at Mikado (West Greenbush) of a similar quality. All the clays of the county are Pleistocene or surface clays, and it is the almost universal rule that such clays have more or less calcium and magnesium carbonate. Generally the top of the bed is free from carbonates, which have been leached out.

Just at Harrisville the stream falls over a smooth, well-bedded clay, apparently an old lake clay free from pebbles. If not, it could easily be washed free by the stream.* Back of Sturgeon Point, on Sec. 25, T.

* As at Sebewaing, see Vol. VIII., Part I.

27 N., R. 9 E., are fields where a similar clay appears to be present, but it is particularly well exposed where the Black river opens out from the hilly moraine country to the swampy land of the old lake bottom on Sec. 3 of the same township and Sec. 34, just north. Here a calcareous clay is extremely well exposed in the bed of the stream, appearing almost as though it were bed rock. But probably the same bed of clay also appears in the bluffs of the outer valley above the flood plain and at least 10 feet above the river. Here it is light reddish in color, does not effervesce with acid, lies close to the abandoned track of an old logging railroad, and could be readily worked. I should think it would make unusually good brick and tile (see analysis below), though it is quite possible that farther working and testing with auger would show that in going deeper more lime was encountered. Still it is quite likely that an important top layer may have been leached free.

There are indications that similar clays occur all the way along, but somewhat below and nearer the shore, the highest former shore line of Lake Huron (645 to 655 A. T.).

The Au Sable river also flows at several points over firm, well-bedded pink clays, apparently free from pebbles but full of lime. A good place to observe them, however, is in a little side stream at Bamfield's, Sec. 11, T. 25 N., R. 5 E., where they are well exposed.

Three typical samples of the clays were sent to the McMillan Chemical Laboratory, Albion, for analysis, and the following reports were received from Prof. Delos Fall:

	910.		911.		912.		Millbury, Ohio.
Free sand	13.98		11.53		38.55		
Combined silica	27.60		25.71		22.73		
		41.58		37.24		61.28	61.03
Alumina	12.58		7.08		16.37		
Oxide of iron	3.59		3.99		5.59		18.10
							6.65
Calcium oxide	13.04		17.70		2.33		1.29
Carbonic oxide	16.26		21.00		.....		
Calcium carbonate		23.28		31.60			
Sulphur anhydride	0.41		0.41		0.67		1.55
Magnesia *	6.44		6.52		1.21		
							.53
Organic matter	3.72		3.46		9.14		9.20
	98.62		97.40		96.59		
Difference, principally alkalies	1.38		2.60		3.41		
	100.00		100.00		100.00		

No. 910 is the ordinary calcareous clay or marl of the district from Black river near the water level, and is free from pebbles or grit. It will be seen that it is composed of about ⅓ very fine sand or rock flour, ⅓ clay proper, and ⅓ dolomite. It may be used for making brick, but will yield a light brick that will not stand hard burning.

Samples of clay from the Au Sable valley appear to have similar composition.

No. 911, from the old brickyard southeast of Harrisville, is a typical tile clay and contained some small limestone pebbles. It will be seen

* There is not enough CO_2 to combine with all the lime and magnesia. Hence there is probably some hydrous magnesian silicate present.—L.

that it contains even more lime, nearly half. Neither of the clays appear to be suited to the higher uses for clay.

No. 912, the third clay, which lies over No. 910 and may be derived from it by solution of the calcareous material, is of an entirely different character. If the silica is finely divided enough, and I think it is, it would make an excellent clay to mix with Portland cement for the manufacture of marl. I have given an analysis of the Millbury, Ohio, clay, which is largely used in the state for cement manufacture, for comparison.

It would also make an excellent grade of red brick, and very probably also paving brick. It remains to be seen by a series of borings how much of this clay there is, but in all probability field tests showing whether it effervesces with muriatic acid will be sufficient to show this.

WATER POWER.

The following data concerning the water power in Alcona county have been furnished by J. H. Killmaster of Harrisville, who has a general acquaintance with the conditions throughout the county:

"Generally speaking, dams of 10 to 14 feet head could be maintained on the south, west and east branches and main stream of Pine river, with horse power from 40 to 200, according to location, the farther down the stream the larger the volume. The same thing may be said of the streams flowing into Hubbard lake and of Black river. The portion of Wolf creek in Alcona county carries but a small volume, but in Alpena county it becomes a stream of considerable volume.

"On Pine river there is a dam on the east branch at Killmaster village with 12 feet head and an average of about 40 horse power for the season. There is a 48-inch turbine wheel here, but the volume is not sufficient to supply the wheel except during the spring freshet. In the summer the wheel will exhaust the water in about 4 days, so that the stream will not furnish the wheel more than 4 days a week.

"The other tributaries of Pine river have about the same volume as the east branch at Killmaster, at corresponding distances from their sources. A dam could be constructed at the junction of the east and west branches in Sec. 3, T. 25, R. 8 E., that would give a head of 10 or 12 feet, and the supply of water would probably supply a 60-inch turbine wheel, for the power should be at least 150 horse power.

"There is a dam on Sage (McGillis) creek in Sec. 33, T. 26, R. 7 E., with 12 feet head. The stream is small and the power of no consequence.

"A dam at the head of the south branch of Thunder Bay river, just below the point where it leaves Hubbard lake, has 6 feet head, and there is probably about 200 horse power.

"A dam on Sucker creek in Sec. 5, T. 27, R. 8 E., has 10 feet head, with power about the same as at Killmaster.

"On Hubbard creek, in Sec. 24, T. 27, R. 6 E., there is a dam with 12 feet head and a power about the same as at Killmaster.

"There is a dam with similar head on Wolf creek, in Sec. 31, T. 28, R. 6 E., with a greater volume than at Killmaster.

"The dam at Black river has 10 feet head and probably there is 50 horse power.

"The dam at Harrisville is on a stream which would furnish per-

haps 15 or 20 horse power. There is an abandoned dam beside; between them there may be 20 feet fall."

In his report on the Water Resources of the Lower Peninsula of Michigan, State Geologist A. C. Lane notes that the Au Sable river has splendid unused water powers, especially through the stretch from Mio in Oscoda county to T. 24, R. 6 E., in Iosco county, which embraces the portion of the stream in Alcona county.*

SUBSURFACE GEOLOGY.

BY A. C. LANE.

Search for rock exposures along the shore and the Au Sable river, the two regions most likely to show them, has been fruitless, and no rock exposures have been met incidentally. Nor has inquiry led to any authentic exposures. Along the rapids of the Au Sable, however, there are blocks of sandstone apparently belonging to the Marshall series, which may indicate that sandstone is not far beneath. The drift at Bolton, Sec. 35, T. 25 N., R. 6 E., shows abundant Marshall sandstone fragments, and it is conceivable that some of the streams may show rock exposures. But none of the places that we examined proved to be such, merely hard, very clayey till of the ground moraine.

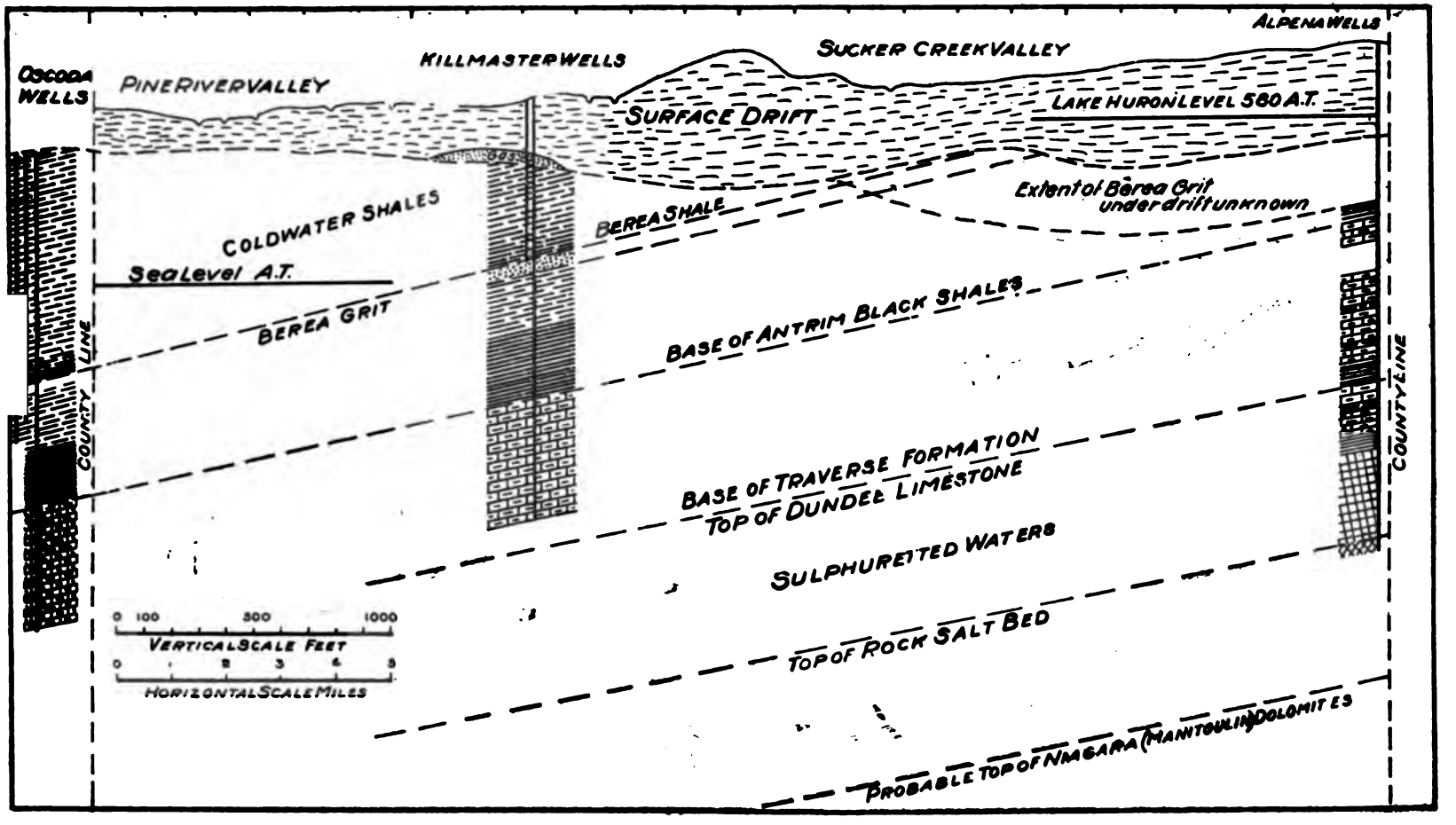
We are mainly dependent, therefore, for our knowledge of the rocks beneath upon borings in this and adjacent counties and upon our knowledge of the general geology, checked somewhat by certain facts as to the character and arrangement of the surface deposits.

In regard to the general lay of the county, we may note that the rocks of the Lower Peninsula of Michigan, as has been long ago pointed out by geologists, lie in a basin whose center is somewhere near Midland county. Thus, for instance, the limestone formation which appears in the Griffin quarries three miles northeast of Omer can be traced southeast to the lake shore, over on the Charity islands, at Bayport in Huron county, and so down to Jackson county, and thence curving northwest past Bellevue to Grand Rapids. Not only do its outcrops lie in this great curve, but the formation is found in borings beneath Midland.

All the coal of the State will be found practically within the basin made by this limestone formation. Thus no coal in commercial quantity will be found in Alcona county, as it lies outside the basin, and the rumors of coal are mainly founded upon the occurrence of black shale, as will be later described.

* Where the south branch of Black river reaches the old line on Sec. 3, T. 27 N., R. 9 E., it is flowing rapidly, with clay bottoms and banks. It has something like 25 miles of drainage area, with numerous springs and would make a good dam site. Thence to Black river is practically dead water, until close up to the mouth where there are two dams, one ten feet and one six feet, both now used more for lumbering operations than anything else. Such powers as we have mentioned ought to make nice electric light stations for small towns if nothing more.

Of a very different character is the Au Sable. This is a large stream fed with numerous springs. At many places along its banks bluffs rise from 60 to over 100 feet high, and in such cases often the upper two-thirds or so of the bluff is sand, the lower clay, and at the base of the sand are extensive springs. It is a remarkably meandering stream for a stream of such a rapid flow and fall. Betwen Flat Rock, near the south line of Sec. 33, T. 26 N., R. 5 E., and Hamfield's place, there is about 20 feet fall. Thence to Sec 16, T. 24 N., R. 16 W., the river drops about 200 feet, 55 feet of it in the stretch known as the rapids, which lie in Iosco county. The drainage area, above where it enters the county is not far from 1500 square miles. From a rough estimate of velocity and size I should think that it was discharging in November, 1901, about 1100 cubit feet per second, while in summer the discharge may fall to half that. Gagings upon this stream at the Tucker farm bridge say, or somewhere above the in-flow of the Pine river and also of the Pine and Black rivers, would easily give us more definite ideas, and an application should be made to the U. S. Geological Survey for a gaging station.—L.


Oscoda Wells
Pine River Valley
Killmaster Wells
Sucker Creek Valley
Alpena Wells
Surface Drift
Lake Huron Level 580 A.T.
Extent of Berea Grit under drift unknown
Coldwater Shales
Berea Shale
Sea Level A.T.
Berea Grit
Base of Antrim Black Shales
Base of Traverse Formation
Top of Dundee Limestone
Sulphureted Waters
Top of Rock Salt Bed
Probable Top of Niagara (Manitoulin) Dolomites
County Line
County Line
0 100 500 1000
Vertical Scale Feet
0 1 2 3 4 5
Horizontal Scale Miles

Moreover, since Alcona county lies in the northeast of the center of the basin, we may expect that the rocks, if there is no irregularity, will dip, and any particular bed will be found deeper, to the southwest.

The exact direction of the dip may not always be the same. The directions at right angles to it, known as the strike, are given approximately by the course of the north side of Thunder bay, and the rock ridges north of Alpena, and seem to be very close to northwest and southeast, though if the reef[1] about 7 miles off Harrisville in 14 fathoms of water is a solid reef of limestone, it may be more nearly N. 37½° W.

Now there is but one set of wells to bed rock in the county, those at Killmaster, and they are so near together that it is not very safe to infer dips from them. So in estimating what kind of rocks a section down into the earth would show we have taken into account wells immediately north around Alpena, south around Au Sable and Oscoda.

A few words as to the names of the rocks may not be out of place.

The unconsolidated deposits are known as surface or drift, and are either sand, gravel, stratified clay, or a stony or bouldery, poorly stratified clay known as till. Aggregates of vegetable matter known as peat or muck, and of calcareous matter known as tufa or marl, also occur.

A consolidated sand is known as a sandstone. Other rocks, when they or their drillings are granular or crumbly in texture, are sometimes called, mistakenly, sandstone.

A fine-grained sandstone, the individual grains of which are angular with good cutting edges, is known as a grit.

A consolidated clay which easily splits, is known as a shale. They may be of various colors, most usually blue, also white (often called fire-clay), red (especially near salt water), green or black. The black shales are often mistaken for coal, but though they contain some combustible matter, in the region of which we are talking it is but 20 per cent or less, and they have no commercial value. Limestone is composed mainly of carbonate of lime. When magnesia takes the place of the lime largely, it is known as dolomite. A blue color generally indicates more or less animal or vegetable matter or clay. A limestone with clay is said to be argillaceous, with sand, arenaceous.

The record of the wells must be taken from reports, as samples have not been preserved, but only in a few cases indicated do I suppose the description to be seriously wrong.

KILLMASTER.

At Killmaster three wells were put down, one about 10 rods from the bridge on the east side of the stream and about 500 paces N. 1000 W. of the south line of Sec. 22, T. 26 N., R. 8 E. Its elevation is near that of the Gustin Station, i. e., about 670 A. T. It was the last put down[2] and the deepest (1530 feet). It is said to have had 150 feet of 10-inch casing, 240 of 8-inch to bed rock, and 614 feet of 5⅝-inch to case off salt water, the hole being dry the balance of the way. There is said to be 600 feet of casing in it still, not now to shut off the brine, for it is put in with

[1] Fishermen bring up pieces of honeycombed limestone in their nets and say that the cavities are used by trout to lay their spawn where it is protected from other fish. The same phenomena are reported by Bell from the Manitoulin Islands on the opposite shore of the lake; Bull. Geol. Soc. Am., Vol. 6, p. 297. It also occurs off Sand Beach and Charlevoix.

[2] 1892 by Hawes & Woodward, of Findlay, Ohio, with cable tools costing about $5,000.

a perforated screen at the bottom, but so as to ensure that the brine pump which was once planned should draw the brine from the bottom. However, this inside casing is now stopped up at 306 feet, as that was as far as I could let a thermometer down. Moreover, when it is bailed out it remains for some time at a different level from the water between the two casings, which rises to the top of the inner casing and slowly flows into it. It is a strong brine, a little from the top giving a specific gravity of 1.105 and 40.6 ounces of it yielded 6.5 ounces of salts, i. e., 15.9 per cent.[1] The temperature at 302 feet is about 50° F. The record is as follows:

Surface Deposits:		
Sand, then till, no gravel at the bottom.....	240	240
Coldwater Shale Series:		
Sandstone	4	244
Gray shale	6	250
Sandstone	4	254
Gray shale	276	530
Berea Shale:		
Red shale	20	550
Black shale	20	570
Berea Grit:		
Sandstone: Gas in top of sandstone, and a very small quantity of oil, which was overcome by salt water in the sandstone below the gas. However, bubbles of burning gas (not H_2S or CO_2) are now coming up continually in the water, which analyzes as given....	40	610
Devonian (Antrim[2]) Shales:		
Gray shales (compare Bedford shales).....	150	760
Dark shales (compare Cleveland shales).....	150	910
Gray shales (compare Erie shales).....	25	935
Dark shales (compare Huron shales).....	65	1000
(The top of the Traverse may be here.)		
Gray shale and limestone.....	32	1032
Black shale (compare Huron shale).....	58	1090
Limestone, color varying from light to dark....	440	1530
Traverse (i. e. Hamilton):		
The first few feet are—		
Hard limestone	8	
Soft limestone	80	
Hard limestone	90	
Hard limestone	4	
Soft limestone	20	

[1] These gave Prof. F. S. Kedzie on analysis:

$CaCl_2$	11.53% of the salts, i. e. 1.821% of the brine		
$MgCl_2$	3.56	.562	
$FeCl_2$	.20	.032	
Water of crystallization	6.14		.971
K	0		
Br	0		
NaCl (salt)	72.21	12.514	
	100.64	14.929 solids.	15.9

A brine of this strength should have sp. gr. of 1.111, according to Winchell's table, but this is avowedly not very accurate, and neither are my weights on common country scales.

The brine is remarkably free from sulphates and would give a very high grade of salt, and I think it more than probable that the sample taken was somewhat diluted.

[2] Term introduced to replace St. Clair, which had been elsewhere used in another sense. It covers the strata from 2306 feet to 2585 feet in the well of Plate VI, Vol. V, of our reports.

Hole No. 1 is about 80 rods from No. 3, nearly south, but a little east of it, and was the first put down. It is 10 feet by hand level above No. 3. It went only 600 feet, stopping on a hard bed which was supposed to be limestone at first but was afterwards thought, and doubtless rightly, to be the hard upper crust of the bed encountered at 570 feet in No. 3. A dip to the south of between 30 and 40 feet is thus indicated.

The formations were similar to those in No. 3, except that there was a bed of gravel at the bottom of the drift, which served as a reservoir for gas. This showed a registered pressure of 103 pounds (apparently the direct water pressure). This gas was overcome by a large flow of fairly fresh water, which was encountered when the 6-inch casing was driven through the gas vein into the sandstone rock. The well was bored wet with pole tools. At first the water gushed up with 40 feet head or so, but now it barely flows. It still yields, however, a considerable quantity, converting the neighboring land, though 20 feet above the stream, into a cat-tail marsh. The water has a Sp. gr. of 1.005, gives strong reactions for calcium and chloride, but practically none for sulphates. The temperature of this slowly-flowing water is 47° F., about 3° less than the temperature at 307 feet in hole No. 3, and 3° F. more than spring water.

The deep hole, No. 3, was dry below the Berea Grit.[1] At 1000′ or 1090′ the black shales occur which are so widely diffused in the drift and outcrop at Partridge Point and Thunder Island. The base of these black shales is shown in two wells, put down by the Alpena Business Men's Association.

ALPENA COUNTY WELLS.

The wells just mentioned were one on the north line of Sec. 22, T. 29 N., R. 8 E., and the other on the east and west center line but a few feet from the water and a few feet above it. I have seen samples from the wells, and the base of the black shale appears to come shortly below 63 feet in No. 1, below 76 feet[2] in No. 2. This would indicate a drop of more than 32 feet per mile to the south or 45 feet per mile to the southeast, for the northernmost well is the more westerly. These wells are almost directly north of Killmaster, and supposing the black shale in the Killmaster well to be at 1090 feet, we have a dip from the No. 2 well to the Killmaster No. 1 of[3] 38.4 feet per mile, or 53.7 feet per mile to the southwest.

Comparing holes Nos. 1 and 3 at Killmaster, we found a similar dip, and the same rate is indicated from the exposures of the base of the black shale on Partridge Point, just north.

The dip around Alpena is reported by Mr. A. W. Grabau as also about 30 feet to the mile to the south, i. e., 42 feet per mile to southwest.

At Alpena there are three wells over 1000 feet deep, from which we may obtain an idea of the strata which may be met from the black shales down to the rock salt. The record of the Churchill well was as follows:[4]

---

[1] Accordingly it did not read the Corniferous or Dundee limestone.

[2] At 76 feet is black shale, at 81 to 83 feet is green shale, the rest is limestone.

[3] $\frac{(590 - 73) - (670 - 1090)}{24\frac{1}{2}} = 38.4$

[4] A summary is also given by Mr. Grabau later in this report.

RECORD OF THE CHURCHILL WELL.

1891.	Character.	Feet.	Total.	Per day.	Hours.	Remarks.
Oct. 29	Sand.....	39	39	39	6	Struck light vein of fresh water.
30	Boulders...	2	41	2	12	Surface pipe to rock.
	H. w. l*.....	7	.....	7	6	
Nov. 2	"	8	.....	8	12	
3	"	5	.....	5	12	
4	"	5	66			
	Shale.....	9	75	14	12	
5	H. w. l.....	16	.....	16	24	Rock very hard.
6	"	16	.....	16	24	1 hr. lost callipering.
7	"	17¼	124¼			
	Shale.....	2¾	127	20	24	
9	H. w. l.....	18	145			
	Granite.....	3	.....	21	24	Extra hard gray limestone.
10	"	5	153			
	H. w. l.....	14	167	.....	.....	Delayed 35 minutes on account of bit.
	Shale.....	5	172	24	24	
11	Shale.....	15	187	.....	.....	Working in blue shale.
	H. w. l.....	13	200	26	24	
12	H. w. l.....	21	221	24		
	Shale.....	3	224	.....	.....	3 men in each watch.
13	Shale.....	15	239			
	H. w. l.....	10	249	25	.....	Shale, 7 ft. white—Slimy shale.
14	"	13	262			
	Shale.....	7	.....	20	.....	Very sticky nature.
16	"	20	289	.....	.....	Blue.
	H. w. l.....	15	304	35		
17	"	17	321	20		
	Shale.....	3	324			
18	H. w. l.....	15	339	15	.....	Extra hard.
19	"	11	350	11	.....	Extra hard.
20	"	13	363	19		
	Shale.....	4	367			
21	"	20	387	.....	.....	Shale blue.
	H. w. l.....	5	.....	25		
23	Shale	25	417	25	.....	Lost 6 hrs. by stripping pin from top of jars.
24	Shale (blue).	25	442	25		
25	"	2	444			
	H. w. l.....	10	454	12	.....	Extra hard.
26	"	7	461	7	.....	Extra hard.
27	"*	6	427	.....	.....	Light vein flowing Water now flowing.
	H. g. l.....	5	469	8	.....	Extra hard.
28	"	5	474	5	.....	6 hrs. lost by sickness of one man.
30	"	10	484	10	24	
Dec. 1	"	10	494	10	.....	Strong flow of mineral water at 489 ft.
2	"	10	504	10	.....	Flow still continues shale caving in.
3	Granite*....	6	510	6		
4	"	7	.....	7	.....	Flow shows stronger.
5	"	6	.....	6	.....	Flow unabated, rock very hard.
7	"	7	.....	7		
8	"	6	.....	6		
9	"	7	543	7	.....	Increased flow at 570, shows connection with Harrington well.
10	Shale.....	25	568	25	.....	At 590 fresh flow struck which exceeds in strength anything ever struck in Alpena, much stronger of sulphur. At 598 struck another vein of water which shows stronger traces of Mg.
11	H. g. l.....	20	588	20		Put in 588 ft. of casing. At 588 ft. hole reduced to $5\frac{9}{16}$ in.
12	H. w. l.....	13	601	13		
14	"	20	621	20	.....	At 605 another vein of sulphur water struck.
15	"	20	641	20		
16	"	20	661	20	.....	670 shut off now.
17	"	10	671			
	Shale.....	20	691	30	.....	698 perforated pipe.
18	H. w. l.....	20	711	20	.....	Volume of H_2O somewhat stronger.
19	"	12	723	12		
21	"	20	743	20		
22	"	13	756	13		
23	"	16	772	16		
24	"	5	777			
	Sandy lime.	5	782			
	Shale.....	5	787	15	.....	(800 ft.).
25	H. w. l.....	10	797	10		Shut off 790.

* H. is hard, w. is white, g. is gray, l. is limestone. The driller's "granite" is really very hard cherty limestone of the Dundee or Corniferous.

RECORD OF THE CHURCHILL WELL—*Continued.*

1891.	Character.	Feet.	Total.	Per day.	Hours.	Remarks.
Dec. 26	"	12	809	12	.....	
28	"	18	827	18		
29	"	18	845	18	.....	Shut off 794.
30	"	15	.....	15		
31	"	10	.....	10		
1892.						
Jan. 1	"	15	.....	15		
2	"	10	.....	10		
4	"	10	.....	10		
5	"	7	.....	7		
6	"	13	.....	13		
7	"	12	937	12		
8	"	8	954	8	.....	At 936 ft. reduced to 5 in.
9	"	17	969	17	.....	Somewhat softer.
11	"	15	989	15		
12	"	20	997	20		
13	"	8	1,015	8		
14	"	18	1,036	18		
15	"	13	1,056	13		
16	"	20	1,048	20	.....	10 ft. very soft jack, struck what seemed to be the water.
18	"	6	.....	6		
19	.....	.....	.....	.....	12	
20	.....	.....	.....	.....	9½	Put in 601 ft. 2-in. pipe, 4 men.
21	.....	.....	.....	.....	.....	Put in 400 ft. more pipe, 4 hours.
22	H. w. l.	.....	.....	.....	.....	Spent 14 hrs. pulling out 1,000 ft. pipe.
23	"	10	1,072	10	12	
25	"	6	1,078	6	12	
26	"	10	1,088	10	20	
27	"	13	.....	13	24	
28	"	13	.....	13		
29	"	10	.....	10		
30	"	12	.....	12		
Feb. 1	"	10	.....	10		
2	"	12	.....	12		
3	"	12	.....	12		
4	"	10	.....	10		
5	"	12	.....	12		
6	"	12	.....	12		
8	"	13	.....	13		
9	"	12	.....	12		
10	"	12	.....	12		
11	"	15	1,256	15		
12	"	15	.....	15	.....	Struck salt rock; went into rock salt about 20 ft.

There seem to have been casings at 800, 1062 and 1278 feet.

The end apparently corresponds to the rock salt bed, which at St. Clair and all along the St. Clair river occurs 800 feet and more below the top of the Dundee beds.

A number of other wells by Fletcher, Moench and others do not go so far, but go through the shale above into the Dundee limestone for water.*

AU SABLE AND OSCODA WELLS.

These points are as much south of the county as Alpena is north, and yet since there are no outcrops and but one group of wells to bed rock in the county, we are obliged to take them into consideration. Some 11 wells have been put down here within a distance of a mile. We may distinguish in order from north to south three groups, which we may call the Pack group, the Smith group and the Loud group.

Unfortunately, we have no detailed log of any of these wells, but from various recollections, letters and allusions in reports of the salt inspectors we may compile the following account, upon which we may rely with some confidence:

* Which has been analyzed. U. S. G. S. Water Supply Paper No. 31.

The Pack wells are 20 to 25 feet above the lake, the Smith wells about 15, the Loud wells from 6 to 8 feet.

There are 90 to 100 feet of surface deposits, mainly sand. Then down to some 200 feet is a series of sandstones and shales, which yields in the less elevated wells of the Louds a flow of slightly saline water containing from ½ to 1 per cent of salt, at a temperature of about 48° to 50°.

Then blue shales, and occasionally red, predominate, and toward the bottom black shale, the Berea shale, until at 950 feet in the Park wells, 960 in the Smith, and quite likely a little deeper in the Loud wells, they strike the Berea Grit. This holds a strong brine, 90° to 98°, of good quality, as the analysis of Smith Kelly and Dwight's brine shows.[1] But the sandstone is fine-grained and split with, and passing into, shale and does not yield brine freely, though the quality, in its low percentage of sulphates and ratio of earthy chlorides, is that of the Berea brines generally. According to Mr. E. F. Holmes, the sandstone in going north runs out and yields less and less brine.

We find also in Alma, Grayling and western wells that there is little trace of the Berea. Comparing the Oscoda wells and their elevations, it is clear that the sandstone must dip 30 to 40 feet per mile to the south. Beneath this Berea Grit one well of Pack's was drilled to about 1800 feet depth, and is said to have been 1761′, 1785′, 1850′ deep according to various reports, and dry all the way, encountering only blue and black shales with thin streaks of limestone. It is reasonably certain that it could not have penetrated the Dundee (Corniferous) limestones, whose hardness, light colors and mineral waters could hardly fail to be remembered. But it must have gone pretty near to the top of it, and the black shale, in which Mr. Elliott, the driller, says they left off, may have been the Bell[2] or Marcellus shale. This, according to Mr. Grabau, follows the trough of Grand lake north of Alpena, some 50 odd miles north of Oscoda, and accordingly the dip thence to Oscoda would average between 30 and 40 feet per mile.

If the strike of the rocks is supposed to be S. E., the Pack wells in Sec. 34, T. 24 N., R. 9 E., should have the rock at about the same elevation above sea level as Sec. 34, T. 25 N., R. 8 E., near the south line of Alcona county, and we have so assumed in constructing the section (Plate II). According to this the dip from Killmaster would be,[3] measuring on the top of the Berea Grit, about 50 feet per mile to the south. But if the strike is nearer east than south the true dip will be less than 50 feet, but cannot be less than 26 feet per mile, which it is in the direction from Killmaster to Oscoda.

It is unfortunate that we cannot identify the top of the (Hamilton) Traverse in the Oscoda wells and thus be able to compare dips on this horizon with Killmaster and the strata about Thunder bay.

[1] U. S. G. S. Water Supply Paper No. 31-No. 291:

$CaCO_3$	tr.
$CaCl_2$	42.1
$CaSO_4$	tr.
$MgCl_2$	19.3
NaCl	179.3
	241.9 grams per kilogram.

[2] Defined by Grabau in his paper in this report.

[3] (670 — 570) — (55 + 580 — 950) ÷ 8 = 395 ÷ 8 = 49.

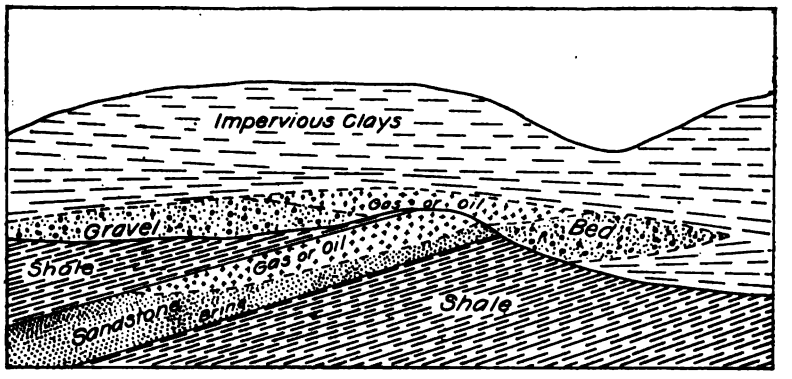
ECONOMIC GEOLOGY.

Oil and gas possibilities.—The Eo-carboniferous series to which the Marshall sandstones and Coldwater shales[1] belong contains a number of "oil sands" in Pennsylvania, but the first horizon which seems hopeful in this State is the Berea Grit. This rarely fails to show some signs of oil or gas. On the west shore the salt wells of Muskegon and Ludington encountered more or less gas at this horizon. So did the wells at Bay City (at 2090′) and Blackmar (at about 1632′).

It is a well-known oil sand in other states, and the Killmaster wells show that it may yield oil or gas in the county if other conditions are right.

The quality of the oil is much better than that from the Canada horizons, which is a heavier oil with more sulphur. The Petrolea oil seems to come from beneath the black shales in the limestone of the Traverse and Dundee beds. The deep Killmaster and Oscoda wells seem to show that the Traverse is not only dry but free from oil or gas. The Dundee or Corniferous, however, has not been struck in the county, though the section shows at what reasonable depths it should be found.

There are other oil and gas horizons underlying the county. The Niagara has one and the top of the Trenton also is a well-known place, which has a great reputation among drillers, but the depth is so great,[2] and the chance of finding anything of value, unless something is found higher up, so small, that for the present they may be dismissed from consideration.



Illustrating possible occurrence of gas or oil. Compare the section on Plate II.

The source of oil and gas is supposed to be animal or vegetable matter buried with the rocks when they were formed, and slowly decomposed, very likely in the presence of salt water. The vegetable matter is supposed to make the lighter oils, which are free from sulphur. The same vegetable matter gives the dark coloring to the black shales which we find both above and below the Berea Grit.

[1] There are beds of shale in the sandstone, and sandstone in the shale.

[2] The Niagara very likely begins not more than 200 or 300 feet below the Alpena rock salt horizon, is liable to be 800 feet thick, and will be succeeded by a series of red, blue and black shales, 600 feet thick or so, beneath which will come the Trenton.

Now the first place in which we might find oil or gas is in the surface deposits. It may occur in these in one of four ways.

(a) In the first place, fragments, stones and boulders of the oil and gas generating strata may be scattered in the surface gravels or till, and the oil and gas slowly collect in pockets or pools under beds of clay, which may serve to hold it down. This may be in part the source of the gas in Killmaster well No. 2. Such gas may occur anywhere in the county and is probably the source of most of the gas of the surface gas springs, but is not likely to be of much value.

(b) In the second place, a porous inclined bed which holds or generates gas may be covered by a gravel bed, and this in turn by clay, as shown in the sketch just given.

In that case the gas and oil may work out from the outcrop into the gravel bed. Part of the Killmaster gas might thus have worked out of the little bed of sandstone below, and accumulated in the gravel.

Now it seems quite probable that accumulations of oil or gas of value might thus have been formed beneath Alcona county. The coating of surface deposits is thick enough to give a good pressure, and usually is clayey and impervious enough to hold the gas down well.

In particular it would seem quite possible that, especially where the Berea Grit comes directly beneath the surface deposits or the black shales above and below it, gravels occurring at the base of the same might be full of oil and gas under good pressure.

If we assume the dip southward of 38.4 feet per mile found above, the Berea Grit will be as high as the rock surface of Killmaster at a point about 8.6 miles north of Killmaster and should be at an equal elevation along the line of strike, that is, a northeast-southwest line* through this point. It is worth noting that Mr. Leverett has not found the white sandstones, such as the Berea and Marshall are, north of a point two miles south of Lincoln, though red sandstones resembling the Potsdam sandstone occur all over the county. Wells along this line would be desirable to test the possibilities of oil and gas in this way.

It must be remembered that the chance of striking moderate quantities of oil or gas enough to supply a few houses are very much more than those of striking very large quantities, such as would warrant starting a new town, so that in planning such wells they should be placed where they would be of use.

(c) In the third place, it is possible that there might be cracks in the earth's crust made by earthquakes, or otherwise extending down into lower reservoirs of oil or gas and allowing them to work toward the surface.

This is a very popular theory of the origin of oil and gas in springs and has caused many thousands of dollars to be thrown away in exporations. There are no indications of such faults and fissures, however. The gas springs around Killmaster are not in a line. The strata of Lower Michigan are not usually much disturbed, and even if they were, a leaky reservoir is no sign of great and valuable accumulations.

(d) A certain amount of illuminating gas, marsh gas, is often generated in swamps directly from the decay of recent vegetable matter, and is of no economic importance.

* Compare the line BB of Plate II.

Attention was called to the possibilities of gas in the county by a number of springs, which either yield inflammable gas continuously or when stirred with a pole. The following notes on them are compiled from notes by Mr. Leverett and myself.

Near the center of Sec. 26, T. 26 N., R. 8 E., there is a boiling spring on the land of the Gustin Land Company which has such a large amount of gas that it led to the Killmaster borings. The gas will blaze two or three feet high when lighted as it issues from the water, without being confined in a pipe. It is at least 10 feet below the level of Killmaster well No. 1, and the temperature of 44° F. one bitter, freezing cold day in November is close to the probable mean annual air temperature, and may indicate that the water comes from some depth. The water is hard and has a little chlorine,[1] but not enough salts to affect its gravity.

In Sec. 14 of the same township there is a gas spring on B. Anger's land in the north part of the section and on Mr. Gunther's land in the west part.

In Sec. 32 of the same township there is a gas spring on land of the H. M. Loud Company. In Sec. 34 there is one on the land of Simpson & Henry. In Sec. 15, T. 25 N., R. 8 E., that is the township south, there are two gas springs on the land of Ambrose Thompson. Aside from the above noted springs, there are said to be numerous places along the east branch of Pine river where gas bubbles up in the bed of the stream.

Mr. Killmaster has also noticed oil in the well of Angus Cameron, Sec. 12, T. 28 N., R. 5 E.

The next place we might expect gas or oil is in the sandstones, and particularly the Berea Grit. They would tend to accumulate in larger quantity here:

(a) Where there is an upward bend or anticlinal in the bed. Of a complete anticlinal or dome there is no evidence. In fact, as we have seen, the indication is of a fairly steady dip to the southwest.

But in a basin like that which is formed by the rock beds of Michigan there are liable to be flutings around the side, folds pitching toward the center of the basin. In such case the strike would veer now to one side and now to the other of its mean course. Now the fishermen bring up on their nets about 7 miles off Harrisville, in about 14 fathoms of water, fragments of peculiarly-honeycombed limestone, over the reef, similar to that described by Bell.[2] If this limestone reef is a real outcrop of bed rock, which is by no means certain, it would probably represent the limestone at the top of the Traverse formation. But in that case the strike from the reef to Partridge Point in Thunder bay would be north of northwest.

Again we may see, comparing the Killmaster and Oscoda walls, that if the dip is no greater than that farther north the strike must be considerably to west of northwest. Thus it is possible that there may be such flutings. In order to find them out, however, it would be needful to have more wells, put down to some recognizable stratum and arranged in a northwest to southeast line, so as to find out accurately the course of the line of strike. Then the points where it is most to the

[1] Ca is strong; SO_4 trace; Cl. low. Sp. Gr. 1.001?
[2] Ante. p. 65.

southwest of its mean course will be the tops of bends which may collect oil and gas.

(b) In the second place the gas and oil might collect in the upper parts of the oil and gas-bearing beds where they were overlain by clay. This is also illustrated in the section of Plate II, as well as in the sketch on p. 71.

In this case we have practically one-half of the anticlinal, the rest being cut away, and its place taken and the escape of gas prevented by the clay. The best places to test this would be the same as those to test previous possibilities,—a belt parallel to the strike and about where the Berea Grit will lie directly under the surface materials. Just where that will be cannot be told, for we do not know how deep it is to bed rock; but if we suppose the elevation of the extreme limits of the Berea Grit to be between that at Killmaster and that of the exposures and wells north, the Berea Grit will extend to somewhere between Harrisville and Sturgeon Point, extending thence northeast and reaching as far as a point about eight miles north of Killmaster. And near this line explorations will be not only cheapest, for the depth will be comparatively slight, but most likely to be fruitful.

Drilling may well be on low ground at first, and valuable flowing wells may very likely be obtained, though of course any flows of water would have to be shut off temporarily in testing for flows of oil or gas.

(c) The Berea Grit is rather an uncertain element, sometimes present and sometimes not, and if areas where it is present and porous are isolated by erosion with a covering of shale and clays, or merely pass by transition into shalier and less porous beds, it is possible that the more porous parts might become reservoirs for gas and oil. For instance, the Berea Grit around Killmaster seems to have been much more porous than at Oscoda.

Areas of this kind might, of course, occur anywhere the Berea Grit occurred; that is, anywhere except in the northeast corner of the county. Here, as the new railroad cuts, for instance, of the "Stone Ridge" on Sec. 35, T. 28 N., R. 9 E., show by the abundance of slabs of black shale and total absence of the Berea Grit, the underlying rock is the Antrim black shale of the Devonian.

I would suggest as appropriate places for test wells for oil or gas, Harrisville very particularly; some point in the Black river valley near the south line of T. 27 N., R. 9 E.; the neighborhood of Lincoln; the valley of Sucker creek, and the eastern shore of Hubbard lake.

If bed rock surface was found unusually high, and the backward curve in the moraines which indicate the ice margin suggest the possibility of such a thing, it might be worth while to explore farther north. But a few wells in the regions suggested, not over 300 feet deep probably, would be very instructive. In particular would I recommend the sinking of a well at Harrisville, not only to see what the oil and gas prospects were, but also with a city water supply in view. It will not be safe to use water from Lake Huron and let sewage go into it also.

Salt.—There are two sources of salt manufacture, natural brine, and rock salt, which is dissolved by pumping down upon. The disadvantage of brine is that it is liable not to be so strong, and to contain so much

earthy chlorides (Ca, Mg) Cl_4, that a large amount of the bittern must be thrown away. On the other hand, the Berea Grit is generally remarkably free from calcium sulphates and not likely to cake, and at 550 feet and lower in Huron county, at White Rock, Port Huron, Port Austin, etc., proved a satisfactory brine and made remarkably pure salt. The sample from Killmaster is not as strong as could be wished, but may have been diluted somewhat with rain water. No doubt south of Killmaster it would be stronger, and if the Berea Grit were porous enough to yield the brine freely would be very satisfactory for salt manufacture.

The brines of the Dundee are too strong of sulphur and other salts than sodic chloride to be good for making salt. But the rock salt at Alpena ought not to be more than about 1750 feet deep at Black river, about the depth it is along the St. Clair river. Moreover, if from the salt one wished to make soda—a great and growing industry of the State—limestone, which is the other chief raw material, can easily be obtained by rail or boat from Alpena county.

As the section shows, the rock salt would soon be quite deep as one went south, and to test for rock salt at Black river or north, one should plan for a well 2000 feet deep.

Water and mineral water.—The county is well watered at present, yet some of the best farming lands are the lands originally marked as swamp lands. These often turn out to be fairly heavy clay lands, as around Gustin and the lower valley of the Pine. Here deep wells will first be needed.

The well water is hard and the stream water is not very soft. The character of the Killmaster water has been already described.

The drift is thick and usually ample supplies of water for domestic use will be encountered in it. Water from bed rock will usually be scarce or slightly brackish, except perhaps in the southwest corner of the county, where wells into rock may strike the Marshall sandstones and find plenty of good water.

The slightly saline waters have a stimulating effect on the kidneys, and waters of the same general type as those first struck at Killmaster and Oscoda when well advertised, as the Apollinaris or Attapah, often have considerable repute. It would be possible to obtain strong saline and sulphureted waters, such as are widely exploited for bathing in the southeastern part of the State.

Peat.—There have been a number of inquiries regarding peat in my office lately. This is now compressed and manufactured into blocks for fuel in Ontario. It has been used for nursery packing, and is the soil for celery, mint, cranberries, etc. There were large areas of swamp originally in the county, but many of these have cleared up into good land and the depth of the peat was not great.

One area not yet touched, however, extends from just north of Alcona in Sec. 2, T. 27 N., R. 9 E., and follows the Black river to the junction of the two branches and up the other one. Here are extensive areas of cranberry bog and tamarack swamp with some sand ridges, which are convenient to the railroad. I do not think the peat is very thick, but do not know, and it would be convenient to develop.

Rumors of coal and lead.—Rumors of the existence of coal in the county may be ascribed to the boulders of bituminous black shale, which will burn

pretty well. In fact in Scotland a similar shale is distilled for the oil in it. It has, however, no commercial value. Fragments of this bituminous shale are abundant throughout the county in the coarser deposits. About a mile north of Alcona the railroad makes a cut which exposes great boulders of shale.

There are also reports of the discovery of lead in the county, but I was not able to find, either in the hands of anyone or in the drift, any lead ore.

The fishermen off Sturgeon Point are said to have brought up lead on their nets and used it in marking barrels. Mr. Perley Silverthorne is said to have done so. Native lead is hardly ever found and the ordinary lead ores cannot well be used for marking, so that I am tempted to believe that it was some substance like black lead, perhaps a black clay, which was thus found.

The Indians are also said to have found lead up the Au Sable river. An investigation of similar rumors in Huron county led me to imagine that they might have sprung from the Indians claiming to have found lead for bullets, for the honest possession of which they could not otherwise account. When later plied with liquor that they might divulge the secret in their cups, they found the process so agreeable that they kept up the illusion. But no amount of liquor could ever reveal the secret, for the simple reason that there was none to reveal.

ALPENA COUNTY.

In the summer of 1900 Mr. A. W. Grabau, then of the Massachusetts Institute of Technology but now of Columbia University, an accomplished paleontologist, whose "Scientific Guide to Niagara," issued by the New York State Survey, must make his name widely known, visited Alpena for us. My object in sending him was in particular to study and call attention to the high-grade limestones of that region. The account of his field work, in which he was assisted by W. F. Cooper, arrived too late for inclusion in my last annual report and was printed in the American Geologist.

Last summer he spent another month on his way back from the summer school of Columbia University in the Upper Peninsula. Some samples collected by him were very thoroughly analyzed by W. E. Brady of the Illinois Steel Co., and we have also a suite of analyses of the Bolton quarry, for which we have to thank Mr. M. J. Griffin.

The results of his studies will be found elsewhere incorporated in a preliminary study of the economic value of the limestones of the State.

Although Alpena county is very interesting in more respects than one, we can hardly prepare an elaborate report until we have a better topographic base. It is, however, one of the best places in the State to collect fossils, and a guide illustrating them for popular and school use should be prepared. A good detailed county report would, however, be worth all it would cost if the topographic base were ready.

KENT COUNTY.

As stated in my last annual report, I seized the opportunity offered by Mr. Nellist's interest to arrange for contour map of Kent county, which would be of immediate service and could later serve as a base for a detailed county report. Unfortunately, I have not had funds to pay him enough to justify his devoting his whole time to it. The map is, however, practically complete as to field work and will, I hope, be ready for publication with this report. In the meantime his notes have been of service to Mr. Frank Leverett of the United States Geological Survey, who has been making studies of the surface geology. Miss Emma J. Cole of the high school has recently published an elaborate list of the plants near Grand Rapids, and Dr. Burton E. Livingston of the Hull Botanical Laboratory of the University of Chicago, basing his studies upon the work of Nellist, Leverett and Cole, has prepared the appended very interesting study and map of the plant societies of the

county, a study of the connection of the botanical distribution with the soils and surface geology.* It is valuable in itself, for it is practically a map of the soils of the county, but it is even more valuable as an excursion into a field lying between geology and botany, agriculture and forestry, and showing the problems which should be studied and solved by judicious coöperation.

Of great importance, if verified, to forestry is his suggestion that it is chiefly the capacity of the soil to retain moisture that determines the distribution of the different societies of trees upon the uplands, and that in this respect humus accumulated by dead leaves, etc., may replace clay, so that little by little even upon a light sandy soil, the jack pine may be replaced by the white pine, and that in turn by the maple and beech.

It will however be essential to study not only the surface distribution of the sand and clay, but also, as has been suggested, the depth of the same.

* This department has been quite active lately in studies of the kind to interest Michigan folk. See the references which Dr. Livingston gives, and also, "In Urwald," a lecture by E. Desor, published in the volume of Oeffenttiche Vorträge, in Basel, 1881. (Boston Public Library.)

THE DISTRIBUTION OF THE PLANT SOCIETIES OF KENT COUNTY, MICHIGAN

BURTON EDWARD LIVINGSTON

UPLAND PLANT SOCIETIES
KENT CO., MICHIGAN.

MORAINE MARGIN
TILL PLAIN MARGIN
CHANNEL MARGIN
CLAY AREA
LOAM AREA

THE DISTRIBUTION OF THE PLANT SOCIETIES OF KENT COUNTY, MICHIGAN.

BURTON EDWARD LIVINGSTON.

INTRODUCTION.

1. *A New Field for Research.*—It is a matter of common knowledge that the vegetation of any extensive area is made up of a greater or less number of plant species mingled and growing together. It is also generally known that these different species naturally fall into a number of somewhat distinct groups, giving to certain tracts of country an entirely different aspect from that of other tracts nearby. One who has traveled about the Southern Peninsula of Michigan can hardly have failed to notice, for instance, the differing vegetations of the pine plains, the oak forest, and the beech and maple forest. There is hardly a single plant found common to the first and last of these groups. They are as distinct as would be so many human commonwealths composed of different races of people. It is with the study of such plant groups that the present paper has to deal.

In some instances the study of these groups of plant forms has been undertaken by geologists, and their part in the work has been marked by the frequent use of the geological term *formation* to designate the groups. The word is still in use by many students of the subject, especially with reference to the larger and more comprehensive complexes. Among botanists the term *plant society* to mean the same thing has been suggested and quite largely used within the past few years. It seems somewhat more appropriate than the other word, on this account, at least, that it implies the idea of an organism and organic unity rather than that of a unity of mere juxtaposition in time and space. The latter word will be used throughout this paper.

A plant society, then, is a group of several or many species growing together over some more or less extensive area, and characterized by an apparent congeniality and community of interest, such that all thrive under the same general conditions. Since for any large area the ground will be occupied, not by a single society but by several, which will alternate with each other in some irregular manner, the next logical step after the determining of the societies themselves, will be to attempt the formulation of whatever principles may underly their arrangement or distribution over the surface of the region. How far success or failure has attended the attempt here made to determine some of the principles which underlie the distribution of the plant societies of Kent county, can be judged better at a later day, but it is hoped that this paper may stimulate and aid the prosecution of similar studies in related regions. Another more special reason for this research is this, that if

the flora of these more thickly settled counties is ever to be studied and recorded, this work must be done soon; the present vestiges of the former primeval flora are fast disappearing.

Plant distribution has been a common subject for discussion among botanical authors for over a century, but (aside from the discovery of a few broad climatic factors which seem to determine the distribution of great vegetation types over world areas) little of a definite and satisfactory character has been attained. This is perhaps in great part due to the fact that *species* and not *societies* have usually been studied, thus causing general principles to be lost sight of in a mass of detail whose organization proved well-nigh impossible. It may also be due, in part, to the broad areas chosen for investigation, and the hasty and superficial study which of necessity resulted. Perhaps this general birds-eye viewing had to be done to prepare the way for more exact work, but it seems that enough of it has now been accomplished. What is needed now, if there is to be formed even an acceptable working hypothesis of the principles of plant distribution, is the careful and exhaustive study of areas of limited extent. Once having these studies at hand, comparisons between the different areas may be instituted, and thus, perhaps, some sort of a universe may be forthcoming from the present chaos.

2. *Literature.*—On account of the comparative newness of what may be termed the *society method* of study, as contrasted with the older species method, there is very little literature which can have any bearing on the present work. By far the most valuable paper which has come to my notice is that by Dr. T. C. Chamberlin,[1] of the University of Chicago, on the native vegetation of eastern Wisconsin. But the development of the society method of study for limited areas has, so far, been almost entirely due to the work of Dr. H. C. Cowles and his students. In his recently published account of the plant societies of the Chicago area[2] Dr. Cowles has given an excellent review of the most important articles upon the general subject of plant societies. It will therefore be unnecessary to enumerate them here, especially since they have no direct bearing upon the flora of the region here studied. In this paper the author makes an attempt to classify the plant societies of the Chicago area according to the physiographic stage of the land which they occupy. For instance, the life history of the flora of a typical ravine in a clay moraine is here traced out in some detail, from its beginning as a small gully in the hillside, through all the physiographic changes accompanying the progress of erosion, to its temporary culmination in a broad flood plain. The thesis of the article is briefly this: that as the physiography of the land surface changes, so must the vegetation clothing it change also. Other papers having a very close bearing upon the historical aspects of our problem are another one by Dr. Cowles,[3] and the still more recent one by Mr. H. N. Whitford.[4] The bearing of these papers upon the conclusions here brought out will be introduced in connection with the development of the present work.

[1] Chamberlin, T. C.: Native Vegetation of Wisconsin. Geology of Eastern Wisconsin. 2:176. 1873—1877.

[2] Cowles, H. C.: The physiographic ecology of Chicago and vicinity; a study of the origin, development, and classification of plant societies. Bot. Gaz. 31: 73-182, 1901. *Idem:* The plant societies of Chicago and vicinity. Bull. Geog. Soc. of Chicago, 2:1-76. 1901.

[3] Cowles, H. C.: The physiographic ecology of Northern Michigan, Science 12: 708, 709, 1900.

[4] Whitford, H. N. The genetic development of the forests of Northern Michigan; a study in physiographic ecology. Bot. Gaz. 31: 289-325, 1901.

3. *Kent County, its Climatology.*—Kent county is so situated that it is traversed both by the southern boundary of the pine forest region and the eastern boundary of the so-called Michigan peach belt. It is also crossed by the Grand river valley, the line of one of the great main channels by which the melting ice of the glacial period reached the Mississippi system and the Gulf, and also the line marking the farthest northern extension within the peninsula of many typically southern plants. The county embraces a rectangular tract of land 24 miles by 36 miles in extent. Its western boundary is a meridian averaging about 23 miles east of Lake Michigan at its widest part. The lacustrine influence upon the climate is probably felt throughout the county. Owing to the comparatively small extent of area, differences in climate between its different parts could hardly be pronounced enough to cause any marked difference in its vegetation. Also on account of the great distance apart of the stations for meteorological observations, if there were lesser differences between the climates of different portions of the county, such would not be brought out by any records which have been made. Therefore a study of these meteorological data will give no clue to the principles underlying plant distribution within our area. The following tables are given here, not that they may be of any use in the present report, but that they may be on hand when this area is to be compared with another. They give the data by months for such stations as lie within or near the county:

AVERAGE TEMPERATURE BY MONTHS FOR THE KENT COUNTY REGION.[1]—DATA ARE IN DEGREES FAHRENHEIT.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
White Cloud	.....	.....	.....	44.6	55.9	65.9	72.0	67.8	61.0	51.6	39.4	27.5
Stanton	23.6	22.6	25.9	.....	54.9	65.6	69.7	65.8	60.5	47.0	33.9	19.3
Muskegon	24.2	21.7	30.2	44.7	55.2	65.5	69.8	67.9	62.1	49.9	36.9	28.2
Grand Haven	24.2	25.0	30.6	43.6	53.7	64.4	68.8	67.0	60.9	49.6	37.1	26.4
Ionia	.....	.....	32.0	46.0	.....	68.2	72.0	69.4	61.2	50.8	37.4	26.1
Grand Rapids	24.8	24.9	31.2	47.2	59 0	68.2	72.3	69.2	62.3	49.0	37.4	30.9
Waverly	.....	21.2	31.8	.....	55.6	.....	.....	69.3	61.6	49.4	37.0	27.1
Hastings	23.4	25.0	31 6	46.0	57.7	67.7	71.2	68.7	61.6	49.4	37.4	29.6
Allegan	23.7	24.2	33.8	47.7	.....	68.6	72.2	69.3	63.1	49.1	37.5	30.2

[1] These tables are compiled from the reports of the Michigan section of the U. S. climate and crop service.

AVERAGE PRECIPITATION BY MONTHS FOR THE KENT COUNTY REGION.[5]—DATA ARE IN INCHES.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
White Cloud	.....	.....	.....	2.40	7.15	2.09	2.96	1.32	2.52	3.00	1.37	1.99
Stanton	.....	.....	.....	1.98	.....	.....	.....	1.93	3.34	2.36	2.47	2.05
Muskegon	4.36	2 32	1.85	1.61	2.59	1.48	2.55	1.30	3.27	2.32	2.20	1.76
Grand Haven	2.66	2.21	2.29	2.53	3.42	3.87	2.71	3.67	3.55	3.22	2.99	2.65
Ionia	.....	.....	.....	1.67	.....	2.02	1.94	1.17	2.84	1.97	1.99	2.36
Grand Rapids	2.87	2.76	2.18	2.74	3 34	4.53	2.82	2.56	3.12	2.91	3.15	3.09
Waverly	.....	1.94	3.18	.....	2.58	.....	.....	1.22	4.20	2.13	3.11	2.59
Hastings	2.60	2.03	2.12	2.68	4.02	4.06	2.26	2.74	3.12	2.62	3.11	2.98
Allegan	2.42	2.22	.....	2.66	4.50	2.67	2.73	2.33	3.07	2.47	2.77	2.98

4. *Geology of the County.*—The bed rock of the area is almost entirely covered to a great depth by glacial drift, only a few small outcrops being found within its limits. A small portion at the northeast angle is underlain by the Jackson coal-bearing strata, a correspondingly small area in the extreme southwest is underlain by the Marshall sandstone, and all the intervening drift rests upon the formations of the Grand Rapids group.[6] The drift is so deep throughout the county that the underlying rock layers have apparently no influence upon the vegetation.

The drift itself presents some very interesting features[7] and, since these have an important bearing on the problem of vegetational distribution which confront us, it will be necessary to describe them in some detail.[8] The land consists, in general, of two great blocks of till upland lying on either side of a much lower gravel and sand plain of varying width, which extends in an irregular line from about the middle of the northern boundary (see map, Plate III) southward through Cedar Springs, Rockford, Plainfield, Grand Rapids, Fisher, Carlisle and Ross, and cutting the southern boundary about three miles east of the southwest angle of the county. This plain traces the path of the outflowing water as the Michigan ice sheet retreated northward at the end of the last glacial epoch. An indentation or embayment in the southern ice margin during this retreat marked the junction of the two lobes of the glacier, the eastern lobe coming from the region of Saginaw bay, the western from that of Lake Michigan. It was naturally into this embayment that much of the water was discharged during the melting process, and the line of sandy plains just traced marks, from Carlisle northward, the path of this gradually retreating notch in the edge of the ice. Southward of Carlisle the Green lake sand and gravel plain (in Allegan and Barry counties) originated in the same way.

[5] These tables are compiled from the reports of the Michigan section of the U. S. climate and crop service.

[6] See Geological Map of Lower Michigan, compiled by A. C. Lane, Mich. Geol. Sur. V, 1883.

[7] For aid in interpreting the glacial topography I am indebted to Mr. Frank Leverett, of the U. S. Geological Survey.

[8] A brief description of these features, by Dr. A. C. Lane, will be found in the introduction to Miss E. J. Cole's Grand Rapids Flora. Grand Rapids, 1901.

Three well marked terminal moraines lie partly within this area. The one earliest formed merely bends across the southern boundary, lying south of a line drawn from Ross to a point about two miles east of Carlisle, and thence out of the county in a southeasterly direction to Middleville and Hastings (Barry county). When this material was deposited, the embayment between the two glacial lobes had its head north of Green lake (Allegan county), and its outflowing water found its immediate outlet southward. It formed by its outwash the great triangular plain—which I have designated by the name *Green lake*—bounded on the north by a line drawn from Green lake to Irving (Barry county), and on the west by one from Green lake to Bradley (Allegan county). This plain and its margins being the only regions studied south of the Kent county line, it was thought unnecessary to include it on the map. The highest point of the moraine just mentioned is just east of Corinth. This is the junction point of the two moraines formed from the Saginaw lobe on the east and the Michigan lobe on the west. Thus the high land lying to the east of a line joining Green lake and Corinth is composed of materials from the region of Lake Huron and farther north, while that to the west is composed of drift from the Lake Michigan and Lake Superior region.

The second moraine passes through the middle of the county. Its southern edge is marked by the Grand river valley, its eastward termination being the margin of the plain of Flat river. The escaping water, at the time of its formation, found its way out to Lake Michigan apparently by two channels, one being the present valley of the Grand from Grand Rapids westward, the other extending directly southward to Ross, where it also began to bend toward Lake Michigan. The highest point, marking the junction of the two lobes, lies north of Plainfield.

The northernmost moraine has its highest point northeast of Cedar Springs. The sand plain formed by the outwash here extends from a point about three miles north of Cedar Springs south through Edgerton to Rockford. Its width north of Edgerton is from four to five miles, but near this village it begins to narrow rapidly and is joined by the Rouge valley. South of here the outflow of water cut a deep channel about one-half mile wide through the last moraine described, from a point about a mile and one-half north of Rockford to Childsdale. There the glacial stream entered the plain of the previous outwash. Following the old line of flow it cut a new channel in the already existing plain. Where the old plain divides, south of Grand Rapids, the newer channel is found to do the same. One of the branches follows the present Grand, being, of course, much wider than the flood plain of that stream and extending from the moraine margin about two miles farther to the southeast than the line of the Holland division of the Pere Marquette railroad. This railroad roughly traces the marginal line of the present flood plain. The other channel extends from the point where the Michigan Central railroad leaves the Grand Rapids & Indiana railroad, southward to Ross, thence southwest to Lake Michigan.

Besides the plains just described, there are very pronounced though narrower sand-gravel plains forming the valleys of the Rouge and Thornapple rivers, and a broader one through which the Flat river meanders.

Most of the surface soil throughout the country is predominantly

sandy. There is so much sand in the till that almost every creek valley is a miniature sand-gravel plain. Especially is this true of Plaster creek, southeast of Grand Rapids, and of the larger creeks in the northern portion of the county. In classifying soils and designating them on the map, no attempt has been made to distinguish the different gradations between clay and sand. All which could not be termed either clay or sand have been bunched together as loam,—in the broadest sense of that word,—and denoted on the map by dots. More accurate records were made, but it was found that these minor differences of soil bore no apparent relation to the nature of the societies recorded, and it was thought best not to encumber the map with unnecessary details. Clay is denoted on the map by horizontal lines, sand by an absence of any marking. It will be noticed that moraine and till plain margins are not always the boundary lines of soil areas. This is explained by the fact that the sandy soil almost invariably borders and faces whatever escarpment there may be along a moraine or till plain edge; indeed, it often extends back from the edge for several miles on the higher level. This is true for even slight depressions. Anyone who has ridden a bicycle through Michigan must have noticed that where the road is on a higher level it may be hard clay, but where it descends to cross a creek the slopes and bottom of the valley are usually sandy. This illustrates the fact just stated. The process of erosion by which this condition of things is brought about is going on rapidly at present; the creek valleys are becoming more sandy rather than less so. On account of their small area, no attempt has been made to map these sand and gravel deposits. They are to be understood as existing along most of the creeks and about many of the lakes.

METHODS.

The studies here reported were begun at the suggestion of the State Geologist, Dr. A. C. Lane, in the autumn of 1900, and were completed in the summer of 1901. The author's previous botanical study in the vicinity of Grand Rapids, although not made definitely for this purpose, has been of value in the present work.

Owing to the large proportion of cultivated land in the county, and the correspondingly small proportion which is in an approximately natural state, a study of the natural plant societies is necessarily a difficult one. In the middle of a section, and hence farthest away from the roads, is usually quite a stretch of wooded land, and throughout much of the county these wood lots at the rear of the farms have been the field of observation. From these areas, taken here and there,—samples of the original vegetation, as it were,—an attempt has been made to reconstruct, as accurately as possible, the plant societies which occupied the region at the time of settlement. The effects of pasturing in these wood lots have been allowed for as far as possible. Information has been gathered from local residents as to the nature of the forest which was removed in making certain fields ready for the plow, and has been of great service in some instances.

The vegetation of the area falls naturally into two groups, that growing on what is commonly termed dry ground and that found in moist or swampy places. Each of these groups can be separated into several

societies, which often merge gradually into one another so that in some localities it appears that we have a mixture of several of them. But in general the division is sufficiently well marked. In the following discussion the two primary groups will be taken up separately.

THE UPLAND SOCIETIES.

1. *The Societies Characterized.*—The range of altitude over the whole county is less than 400 feet, so that absolute altitude itself, with its concomitant variations in climatic conditions, is not a factor in the distribution of the flora. Differences in *relative* level, however, produce marked variations in the drainage, and hence in the water content of the soils. This is an important factor in plant distribution.

The vegetation of the upland falls into five societies, which may be characterized as follows:

I. Beech-maple Society, comprising as predominant and characteristic the following plants: Beech, sugar maple, enchanter's nightshade (Circæa), wild licorice (Galium lanceolatum), wood nettle (Laportea), catnip (Nepeta), pokeweed (Phytolacca), richweed (Pilea), nightshade (Solanum nigrum), and red-berried elder.

II. The Maple-elm-agrimony Society, comprising: sugar maple, American and rock elms, agrimony, spikenard (Aralia racemosa), honewort (Cryptotænia), spice-bush (Lindera), moonseed (Menispermum), black snake-root (Sanicula), and wild black cherry.

III. The Oak-hickory Society, comprising: white and red oak (*Quercus rubra-coccinea*), slug-bark and pig-nut hickory, false Solomon's seal (Smilacina racemosa), northern bedstraw (Galium boreale), Aster lævis, and panicled cornel. This society is much the same as the following, but with the addition of the two hickories. It also has many plants in common with the previous society, and may be regarded as an intermediate type between II and IV, both of which are much more distinct. Owing to the difficulty of distinguishing sharply between *Quercus coccinea* and *Q. rubra*, these two forms have been brought together under the name *Q. rubra-coccinea*.

IV. The Oak-hazel Society, comprising: the white and red oaks, Aster lævis, A. macrophyllus, New Jersey tea, hazel, spurge (Euphorbia), Helianthus occidentalis, Solidago cæsia, and hoary pea (Tephrosia). The spurge found in this society is the broad-leaved form. In the following society this plant is just as common and characteristic as here but there it has much narrower leaves. The individuals of the broad-leaved form appear stronger, greener, and more robust than the others.

V. The Oak-pine-sassafras Society, comprising the white and red oaks, white pine, sassafras, plantain-leaved everlasting (Antennaria), wormwood (Artemisia), sand bur, spurge (narrow-leaved form), huckleberry (Gaylussacia), lupine, sweet fern, braken, and Solidago nemoralis. This includes the dryest and most open form of "oak openings" together with the country which was once quite well covered with pine. They are put together here, because aside from the now partially extinct white pine the floras are practically the same.

To one who knows the woods it will be apparent that in these five societies we have a gradation from the close, compact formation of the beech and maple forest, where the sunshine seldom reaches the ground,

to the very open and sunny oak openings and pine plains. It would naturally be supposed that the denser societies are living under more favorable conditions for growth than the more open. This, indeed, we shall find to be the case.

A more extensive list of plants is given in the following table, which shows almost graphically the distribution of the enumerated plants throughout the five societies. The nomenclature is that of the sixth edition of Gray's Manual.[9] The Roman numerals heading the five columns at the right of the names indicate the societies by number, the same method of indication being also adopted on the accompanying map. The letters opposite the plant names show in what societies the plant occurs, the relative abundance in that society being denoted by the letter itself. C denotes common; F, frequent, and R, rare. An asterisk accompanying the letter expresses the fact that the plant is one of those to be regarded as characteristic of that society. Our *rare* has not the meaning given the word by the systematist; plants which he would consider rare are not sufficiently abundant to be considered at all in such a list as the present.

A very complete list of the Pteridophytes and Spermatophytes of Grand Rapids and vicinity has been recently published by Miss Cole.[10]

TABLE OF THE UPLAND PLANT SOCIETIES.

SPECIES.	COMMON NAME.	I.	II.	III.	IV.	V.
Acalypha Virginica	Three seeded mercury	F	F			
Acer rubrum	Red or swamp maple	R	F	R		
Acer saccharinum	Sugar or rock maple	C*	C	R		
Actæa alba	White baneberry	F*				
Adiantum pedatum	Maidenhair fern		F			
Agrimonia Eupatoria	Agrimony		C*	F		
Andropogon furcatus	Beard grass					C*
Antennaria plantaginifolia	Plantain-leaved everlasting					C*
Aralia racemosa	Spikenard		C*	F		
Artemisia caudata	Wormwood					C*
Aspidium acrostichoides	Christmas fern	F*				
Aster cordifolius		F	C	C		
Aster lævis				C	C*	
Aster macrophyllus				F	C*	
Bœhmeria cylindrica	False nettle	C*	F	R		
Carpinus Caroliniana	Blue or water beach		C*			
Carya Alba	Shag-bark hickory		F	C*	R	
Carya porcina	Pig-nut hickory		F	C*	R	
Ceanothus Americanus	New Jersey tea			R	C*	F
Cenchrus tribuloides	Sand bur					F*

[9] Gray, Asa: Manual of the botany of the Northern United States, 1889.
[10] Cole, E. J.: Grand Rapids Flora. Grand Rapids, Mich., 1901.

TABLE OF THE UPLAND PLANT SOCIETIES—*Continued.*

SPECIES.	COMMON NAME.	I.	II.	III.	IV.	V.
Chimaphila umbellata	Prince's pine			R	R	F*
Circæa Lutetiana	Enchanter's nightshade	C*	R			
Cornus alternifolia	Alternate leaved cornel		C	C		
Cornus florida	Flowering dogwood		C	F		
Corylus Americana	Hazel			F	C*	F
Cryptotænia Canadensis	Honewort		C*	F		
Cynoglossum Virginicum	Hound's-tongue	F*	R			
Diervilla trifida	Bush honeysuckle				F	C*
Dracocephalum parviflorum	Dragon head	F*				
Echinospermum Virginicum	Beggars lice	C*	R			
Epigæa repens	Trailing arbutus					F*
Epiphegus Virginiana	Beech drops	C*				
Euphorbia corollata	Spurge			F[11]	C*[11]	C*[12]
Fagus ferruginea	American beech	C*	R			
Galium boreale	Northern bedstraw		F	C*		
Galium circæzans	Wild licorice	F*	R			
Galium lanceolatum	" "	C*	R			
Gaultheria procumbens	Wintergreen				F	C*
Gaylussacia resinosa	Black huckleberry				F	C*
Gerardia quercifolia	Smooth false foxglove			F	F	F
Geum album	Avens		C*	R		
Hedeoma pulegioides	American pennyroyal	F*				
Helianthus divaricatus	Sunflower		R	F	C	C*
Helianthus occidentalis	"			F	C*	F
Hepatica acutiloba	Liverleaf	C	C*	C		
Hepatica triloba	"			C	C*	
Hieracium scabrum	Hawkweed			F	F	C*
Juglans cinerea	Butternut		F	R		
Juglans nigra	Black walnut		F	R		
Laportea Canadensis	Woodnettle	C*	F			
Lechea minor	Pinweed					C*
Lespedeza polystachya	Bush clover				F	C*
Lespedeza Stuvei intermedia	" "					C*
Liatris cylindracea	Blazing star					C*
Liatris scariosa	" "					C*
Lindera Benzoin	Spice bush		C*			
Lobelia inflata	Indian tobacco	C*	R			
Lupinus perennis	Wild lupine				R	C*
Medeola Virginiana	Indian cucumber root	F*				
Melampyrum Americanum	Cow wheat				F	F*

[11] Broad-leaved form.
[12] Narrow-leaved form.

TABLE OF THE UPLAND PLANT SOCIETIES—*Continued.*

SPECIES.	COMMON NAME.	I.	II.	III.	IV.	V.
Menispermum Canadense	Moonseed	.....	C*	F		
Monarda fistulosa	Wild bergamot, horse mint, balm	.....	.....	F	F	C*
Monarda punctata	Horse mint	.....	.....	.....	.....	F*
Myrica asplenifolia	Sweet fern	.....	.....	.....	.....	C*
Nepeta Cataria	Catnip	C*				
Onoclea sensibilis	Sensitive fern	.....	F*			
Ostrya Virginica	Ironwood	.....	C	C		
Phlox subulata	Moss pink	.....	.....	.....	.....	F*
Phryma Leptostachya	Lopeed	.....	F*	R		
Physalis Virginiana	Ground cherry	.....	.....	.....	.....	C*
Phytolacca decandra	Pokeweed	C*				
Pilea pumila	Richweed	C*				
Pinus Strobus	White pine	.....	.....	.....	F	C*
Polygonatum giganteum	Solomon's seal	.....	C	F		
Populus grandidentata	Large toothed aspen	.....	.....	.....	.....	C*
Prenanthes alba	Rattlesnake root	.....	R	F	C*	
Prunus serotina	Wild black cherry	.....	F*			
Prunus Virginiana	Choke cherry	.....	.....	F	C*	
Pteris aquilina	Braken	.....	.....	.....	F	C*
Pyrola elliptica	Shinleaf	.....	.....	.....	.....	F*
Quercus alba	White oak	.....	R	F	C*	C*
Quercus ilicifolia	Black scrub oak	.....	.....	.....	.....	F*
Quercus rubra-coccinea	Red or black oak	.....	R	F	C*	C*
Rhus copallina	Dwarf sumack	.....	.....	.....	R	F*
Ribes Cynosbati	Gooseberry	C*	F			
Rudbeckia hirta	Browneyed Susan	.....	.....	R	R	C*
Sambucus racemosa	Red berried elder	C*	R			
Sanicula Marylandica	Black snake-root	.....	C*	F		
Sassafras officinale	Sassafras	.....	.....	R	R	C*
Smilacina racemosa	False Solomon's seal	.....	C	C		
Smilax hispida	Greenbrier	.....	F	R		
Solanum nigrum	Nightshade	C*				
Solidago bicolor concolor	Goldenrod	.....	.....	F	F	C*
Solidago cæsia	"	.....	.....	F	C	C
Solidago nemoralis	"	.....	.....	.....	.....	C*
Solidago rugosa	"	.....	C*	F		
Tephrosia Virginiana	Hoary pea	.....	.....	R	C*	C
Tilia Americana	Basswood	C	C	F		
Ulmus Americana	White or American elm	R	C*	F		
Ulmus racemosa	Rock elm	R	C*	F		

TABLE OF THE UPLAND PLANT SOCIETIES—*Continued.*

SPECIES.	COMMON NAME.	I.	II.	III.	IV.	V.
Vaccinium Canadense	Blue berry			F	C	C
Vaccinium Pennsylvanicum.	Dwarf blue berry			F	C	C
Vicia Caroliniana	Vetch		F	C*	C	
Vitis cordifolia	Frost grape		C	C		

2. *Distribution of the Upland Societies.*—This is shown by the map (Plate III). From the darkest to the lightest of the five shades used a gradation is shown corresponding to that in the societies from I to V. The sixth and lightest shade denotes deeply-eroded channels occupied chiefly by lowland societies. In these channels the areas occupied by the different societies are so limited that any satisfactory representation of them on the scale of the present map was deemed impossible. Therefore they are left unshaded. Also the lowland societies along the margins of smaller streams and lakes and in swamps among the hills are omitted entirely from the map. The reason for this is in part the same as the one given for the larger channels, and also in part this, that although some of the swamps are large enough to map well on the present scale, yet to trace their margins accurately would require more time than it would be worth, and to map them inaccurately would not be true to the instinct of the work.

Steep slopes where erosion is at present rapid, as along the margins of the many stream valleys and along old glacial channels, are occupied by societies III, IV and V. The character of the soil seems to make no difference here, the drainage being quite complete and the accumulation of humus impossible. It has also been found impracticable to indicate these very narrow areas upon the map.

In the southern tier of townships, all the heavy clay soil, whether it be rolling moraine or level till plain, was originally occupied by the beech-maple society (I). In the lighter loamy soils are usually found the oak-hickory society (III), with transition zones between it and (I) held by the maple-elm-agrimony society (II). The very sandy loam bordering the deep narrow valley of the Thornapple river and spreading eastward from Alaska and Labarge nearly to the Elmdale till plain, is occupied by the oak-hazel and the oak-pine-sassafras societies. This loam is in many places as sandy as the soil of the Grand river sand plain; it might almost have been denoted as sand.

Within the "big bend" of the Grand river is an area of decidedly clayey country occupied by the oak-pine-sassafras society (V), although here the pine is not at all prominent. It appears as though this area were well on the way toward society IV at the time of clearing. But the marked presence of sassafras, wormwood, sand bur, Solidago nemoralis and other forms of society V, make it impossible to classify it elsewhere.

The Grand Rapids sand plain (reaching from Rockford, through Plainfield and Grand Rapids to Grandville and Ross) is generally covered with societies IV and V. The foundation soil is apparently the same throughout, being a gravelly sand, but the areas of society IV have undoubtedly more surface humus, thus giving the soil a darker color and a more loamy texture. The higher parts of the plain, and hence the portions which have been out of water longest, are generally those to show this condition. The lower portions where violent water action probably continued after the main stream receded, and where, owing to the slope, erosion is even now well marked, bear little surface humus and are characterized by society V. Here, at the time of clearing, the pine was usually present. Transition areas between IV and V were covered with "oak openings," however. Of course much of these channel areas is swampy and hence thrown out of the present discussion.

North of Grand river it is only in the western column of townships that the heavy clay is characteristically covered with society I. In other portions of the region the clay is covered with society III, IV or V. It will be noticed that clay bearing the oak-pine-sassafras society is common in the extreme north and becomes less common southward. Societies III and IV approach each other in character as we pass northward. The hickories become less frequent and the general aspect of III becomes more that of IV. It needs to be remarked here also that the stretch of society III reaching from the Rouge river southward and lying west of Grand Rapids is a curious mixture of II and IV. Judging from the trees alone, the southern part of it would be placed in society II, but the presence of New Jersey tea, Solidago cæsia, etc., seem to place it in the oak-hazel group. Sassafras is present here to a remarkable extent and in many places, especially to the north, white pine also. The northern part of this stretch contains much pine. Altogether, the area can better be classified under III than elsewhere. In the general discussion to follow the possible reasons for the mixing will be considered.

In the bit of beech-maple society in the extreme northwestern part of the county is found the only marked instance of the presence of hemlock. This tree belongs typically with the hard wood group in northern Michigan.

In the northern part of the county white pine was almost universally present in the uplands at the time of settlement. This can be proven by stumps which are still in place or have been used in the construction of stump fences. There are pine stumps and a few trees still standing even in the beech-maple group upon areas north of an east and west line drawn through a point about midway between Cedar Springs and Rockford. South of this line the pine disappears in society I and becomes very rare in all but IV and V.

3. *Generalizations on the Upland Flora.*—Any sort of generalization upon a study of such a limited area as the present must necessarily be a hazardous undertaking. I shall venture to call attention to the following points, however, all of which must be looked upon as merely tentative suggestions:

a. *The Soil Factor.*—It appears that the general distribution of the upland societies is based primarily upon the nature of the superficial soil. This must be so since the roots of the smaller plants never pene-

trate very far into the soil, and since in the case of trees and shrubs, seed germination and the growth of seedlings is conditioned by these surface layers. If seedlings cannot develop it is clear that there can be no mature plants.

Surface soils may be classified either according to their chemical or according to their physical nature. The usual soil analyses show the relative amounts by weight of the different chemical constituents. Now it is very probable that the original till material covering Kent county was reasonably uniform in chemical constituents. That it was thoroughly mixed by the movement of the ice sheet is shown by the wealth of different minerals to be found in any small region. But the till has been more or less sorted by water action in many localities, so that in some few cases, almost pure silica is all that remains on the surface. However, in spite of this washing, the most sandy soils contain a considerable amount of other minerals.[13]

But the plant can make use of the soil constituents only after they are in aqueous solution. Now the great bulk of the soil is practically insoluble in water, and it makes no difference to the plant what may be the chemical nature of these undissolved substances. Thus it would be much more to the point to make analyses of the soil water, for it is this which effects the plant directly. Such analyses were not made in connection with the present work; the distribution of the vegetation seemed not to demand it. It is hoped that they may be made at some future time, either for this region or some similar one. It is very probable, however, that soil waters from the surface soil in different parts of this area will be found to be very nearly uniform in their salt content. We are led to this conclusion by two considerations: First, the chemical nature of the soluble part of the surface soil itself is probably very nearly uniform throughout the county. Secondly, the washed soils are usually comparatively shallow, and upward diffusion of dissolved substances probably takes place with comparative rapidity, especially when aided by the soil currents produced by changes of temperature, etc. The only localities where it is at all probable that a paucity in soluble salts would occur in the soil water, are the deep sand plains. There is some rather questionable evidence from the vegetation that such is the case in these localities. More work needs to be done before any definite decision can be made in this regard.

In classifying soils according to their physical nature, the only question which has any direct bearing upon plant growth is that of the ability of the soil to retain water by capillarity, so called. Primarily, this ability depends upon the size of the soil particles. Thus sand will retain less water than loam, and loam less than clay. The three grades of surface soil shown on the map have been indicated with this in view.

Sandy soil may be made to retain more water in two different ways, either by the addition of clay or by the addition of humus. The physical effect of the humus is very well marked. Of course the humus also adds some nitric acid and certain organic materials which are of benefit to the plant, and it also increases the amount of soluble salts at or near the surface; the humus is formed mainly from leaves, and in these organs

[13] Kedzie, R. C.: Analysis of soil of jack-pine plains near Grayling, Michigan. Annual report Mich. Board of Agriculture, 27, p. 211, 1888; also Bull. 99, 1893.

the mineral part of the plant body is concentrated. This is perhaps an important fact in the growth of hard wood upon deep sand which is well covered with humus. Where drainage is complete and rapid, as in sand, and oxidation is also rapid, humus does not readily accumulate; but where it does accumulate as a surface layer, the ability to retain water approaches that of clay.

From the present study it appears that the most important soil factor in the distribution of the flora of Kent county is this one of the relative ability of the superficial layers to retain water. In other words, the controlling soil condition is one of drainage.

Throughout the southern half of the county, soils which retain much water are covered with society I, II or III. The only exception to this is the small clay area within the bend of Grand river. The soil of this area is apparently as good as that farther south, but it is very dry in dry weather. There is no marked humus covering. Perhaps the proximity to the well drained valley on either hand has an influence through underground drainage, but this was not looked into and the question must be left for the present unanswered.

Within the sand plain area of the southern half of the county there are several small stretches of societies I and II. Owing to the fact that at one time a much larger stream than the present one flowed through the valley of the Thornapple river, that valley has a well marked terrace between the country level and the present flood plain. This old flood plain is sandy and corresponds in manner of formation to the Grand Rapids sand plain. But in very many places this terrace is covered with societies I or II. Some of the finest "sugar bushes" which I have seen are here. The sandy soil is thickly covered with a layer of humus. These strips of hardwood are so narrow that they could not well be shown upon the map. The same condition holds on the rather high part of the plain lying west of Crosby. This is indicated upon the map. Also at the base of the escarpment forming the margin of the deeper glacial channel in the Grand Rapids sand plain there are several instances of societies I and II upon humus-covered sand. Notably is this true near the southwest corner of Grand Rapids and on the margin of the Buck creek valley near the Lake Shore & Michigan Southern railroad. In this connection it is interesting to note that beech trees are found quite commonly upon the humus-covered established dunes along the east shore of Lake Michigan.[14]

In the northern half of the county west of the Rouge river we find the heavier soils still retaining societies I, II and III. East of the valley of this river we find the country is much cut up. The clay areas are small and pretty well drained. They may be occupied by any society from I to V. That they can support society I is well shown by its occurrence in several places. Its general absence from this region is perhaps due to another cause, to be mentioned later.

East of Sparta and northeast of Cedar Springs are perfectly typical examples of society I growing upon light soil, the former without trace of pine. In the western part of the Sheffield area I was told by a resident that the clay was at least twenty feet below the surface. But in these areas the soil is deeply covered with humus. What the conditions

[14] Dr. Cowles tells me that he has seen these beech covered dunes as far north as Frankfort, and Mr. Whitford has observed them on Manitou Island.

are which cause the accumulation of the humus in one place and not in another apparently similar place, I was unable to make out. This phenomenon most often occurs in a rather low region where the sand would normally remain moist longer than elsewhere. It has been suggested that the beech cannot grow to perfection in the absence of humus, because of the symbiotic relation of its roots with certain humus fungi. The maple-elm-agrimony society, however, grows to perfection on heavy soil with little or no true humus. It is also found on lighter soil which has a humus covering.

In the southern half of the county it seems fairly clear, then, that societies I and II will grow on rather deep sand if that be covered with humus, and that when society V is found on clay it is well drained and usually with little or no humus. Throughout the county there is an obvious difference in humus content between the areas occupied by societies IV and V, the sand of the former being mixed with vegetable debris. The intermediate society III is found on the loamy soils and on the dryer and better drained clay areas.

b. *The Historic Factor.*—Besides the factor of relative water content in the soils there is another which may be active in this region. I refer to what may be termed the historic factor.

As the ice sheet retreated slowly northward at the end of the last glacial period the portions of Kent county first uncovered were, of course, in the southern part. And the first parts of the sand plains to be uncovered lay also at the south, although these areas were probably under water long after the ice itself had disappeared. It is probable that the pine-heath[15] group which today reaches farthest north, reached well toward the glacier front during the ice age. And at the end of that age, the ice in its retreat was probably followed northward by vegetation, the pine-heath society leading the way. Near the ice margin the soils were probably raw, absolutely without humus, subject to great drought in summer and to extreme cold in winter. These are just the conditions in which we find the pine-heath group today in northern Michigan. It is probable that at one time they occupied all of Kent county, but the climate became warmer and more equable with the farther retreat of the ice, and the growth of the hardy pines, etc., produced a little humus. Their roots fixed the soil so that erosion was less rapid, and perhaps the sassafras and the white and red oaks and the whole of our society V gradually crept in, occupying the better part of the ground along with the pines and heaths. Then as the soil improved the oaks became more and more numerous and the pine seedlings could not develop on account of the shade.[16] The pines thus became fewer in the south and the oaks at last predominant. This would be the stage of our society IV. But the process of working over the soil continued,—though perhaps the ice-sheet had shrunken by this time nearly to its present size,—and humus continued to accumulate in favored places; the hickories, maples and beeches of Ohio and Indiana spread continually northward over every suitable stretch of soil, as fast as it was made fit for them. When the maples and beeches reached

[15] This group comprises, besides several pines, two species of juniper, bearberry, hairbell, braken and several of the other forms found in our society, V. Cf. Whitford, H. N.: *loc. cit.* p. 298 *et seq.*

[16] It is known that pine seedlings fail to mature in the shade of healthy deciduous trees.

maturity in the richest parts of the oak and hickory forest the oaks a hickories probably ceased to mature. Seedlings of these trees fail develop well under maples and beeches, possibly on account of t dense shade. Thus we have reached the stage of our society I.

In such a northward advance, the plant societies would not progre in uniform lines, like a marching army, regiment after regiment. might be supposed at first thought; on the contrary, there would many mixed areas, and the advance would often be almost imperceptib like that of a ragged line of skirmishers. Here and there in a steri perhaps in a well drained portion, would be left a detachment of t advance guard, like the patches of societies V and IV in the southe townships of our county. And these would be surrounded by the lat comers as they crowded on, occupying all soils in which they could co to maturity, and preventing the development of new generations of t forms previously in possession. With these thoughts in mind, a glan at the map will suggest much more than was seen before.

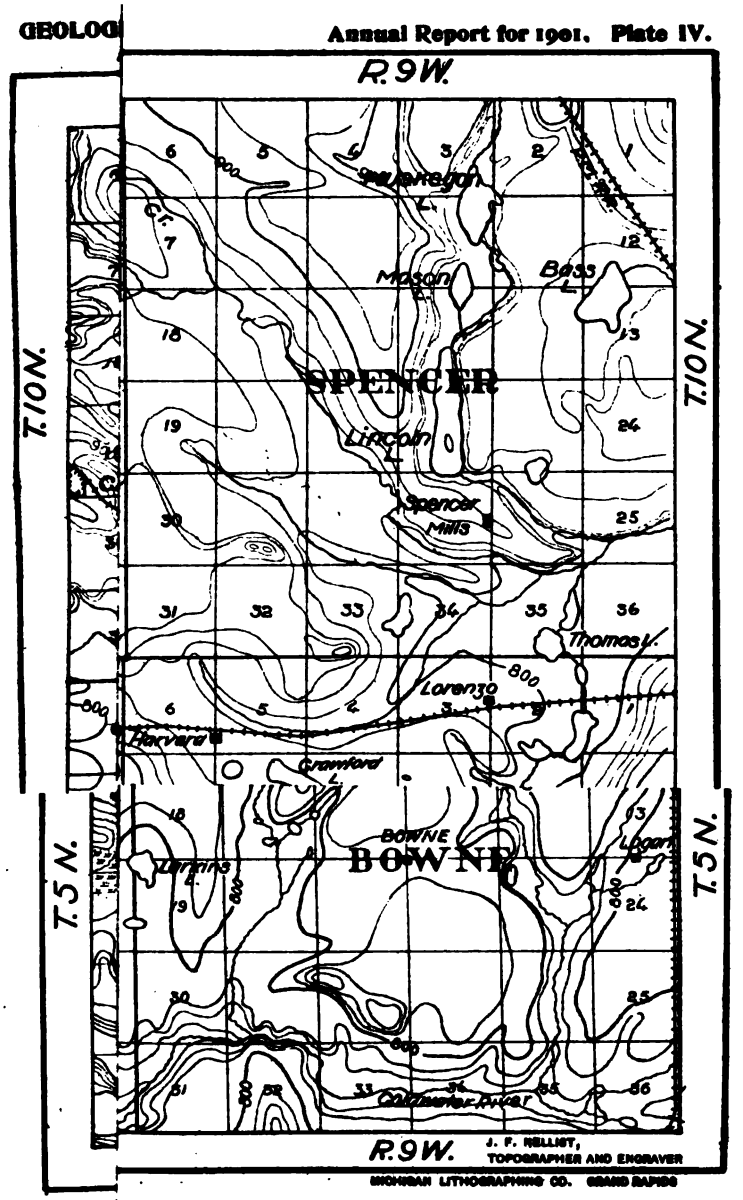
The beech and maple societies (considered by Cowles and Whitford to be the climax society for temperate North America) extend nort ward along the lines of soil richest in water content, and rea farthest north in the western part of the county. This latter fact m be due to the lake influence. Chamberlin states[18] that in Wisconsi the beech is limited to regions near the lake. He believes its distrib tion to be determined by lacustrian climate. This is perhaps partly tr here, at any rate the advance of society I has been much greater alo the side of the county nearest the lake.[19]

Also the other societies,—II, III and IV,—are each a little in advan of the previous one, and each is apparently advancing into the are occupied by the next hardier one. In the extreme north we find almo the entire area occupied by societies IV and V.

According to this line of thought, the reason for the predominance the pine groups in the north is simply that sufficient time has not y elapsed since the glacial period for these areas to be reached by t societies found predominant farther south. Along a wavy east an west line passing through Rockford lies the "zone of tension" betwe societies I, II and III on the one hand and IV and V on the other. Thi line bends far northward at the west, following the western edge of t Rouge valley as far as Kent City and Casnovia. It also bend northward to Sheffield and Harvard on the other side of the Roug valley. Perhaps a climatic factor is operative in producing this zone o tension, perhaps the beech-maple-hickory society cannot occupy larg areas to the north of it. But it seems more probable that the climate,— somewhat colder as we pass northward,—has acted only as a retardin factor, assisted by the fact that a good portion of these northern town ships have a light surface soil, which seems unsuited for the hard woo societies in the absence of humus.

The strongest point in favor of the idea just expressed is found in th fact that at the time of settlement practically all of societies I and I in the northern part of the county were well mixed with pine. In som

[17] Whitford, H. N.: *loc. cit.* p. 302.
[18] Chamberlin, T. C.: *loc. cit.* p. 180.
[19] But Dr. Cowles tells me that in the neighborhood of Chicago beech is found almost exclusively on areas quite far removed from the lake.


GEOLOG
Annual Report for 1901. Plate IV.
R.9W.
T.10N.
T.5N.
SPENCER
BOWNE
Mason
Bass L.
Lincoln L.
Spencer Mills
Thomas L.
Lorenzo
Barvard
Crawford L.
Lansing
Logan
Calhoun River
J. F. NELLIST,
TOPOGRAPHER AND ENGRAVER
MICHIGAN LITHOGRAPHING CO. GRAND RAPIDS

places the pine stumps are so numerous as to raise the question whether the hard wood is not an entirely recent affair. It is probable, however, that scattered maples and beeches were mingled with the pine and that on the removal of the latter their seedlings simply took possession of the ground and shut out the pine seedlings.[20] Also in societies II and III, west of Rockford and as far south as Mill Creek the pine is still pronounced, and in many small spots society IV, or even V, still retains its hold. As has been noted before, this is a mixed group and is hard to classify. There are no traces of pine in the hard wood forests to the southward. It may well be, however, that a further extension of this study will show that this hypothesis of the historic factor is utterly untenable.

Another line of evidence seeming to throw some light upon the historical development of this flora, is that obtained from a comparison of the several sand plains of the region. As was stated in our introduction, there is a well marked sand plain just south of the boundary of Kent county, which we have termed the Green lake sand plain. The soil here is like that of the higher part of the Grand Rapids plain, shown on the map, very sandy, but with a good admixture and coating of humus so that at the surface it appears loamy. The vegetation is made up of all five of our societies. In general the type is that of society III, but there are many spots, especially on the margins of the numerous ponds and lakes where societies IV and V hold the ground. In slight depressions along the margin of the plain the humus is deep and society I is common. There are also many rather large areas of societies I and III well out in the plain. Usually these are in slight depressions, not low enough to be swampy but well covered with humus. We may say, then, that the southern of the three sand plains which have been studied,—and therefore the one which has been out of water and fit for vegetation the longest,—the predominant society is III, but I and II are not uncommon, while IV and V occupy a relatively small portion of the area.

In the Grand Rapids sand plain we have seen that society IV is predominant, with a good part occupied by V and comparatively very little by I, II and III. And in the plain which extends from Rockford northward, the only upland society found is V. Of course the last plain has been out of the water a much shorter time than the other two. In fact, a great part of it is at present swamp and is occupied by lowland societies.

In these three plains we seem to see successive stages of vegetation occupying successive stages in the formation and accumulation of humus. Of course the extensive destruction of the natural vegetation which has taken place since settlement of this region began, will make it impossible for the natural course of events to continue here, even if the above hypothesis be the correct one. Often clearing and burning has reduced the soil from a condition suited to society II or III to one only fit for society V. This is probably also true on the moraines in the

[20] Beal has shown that oaks, maples, etc., can reach a considerable age in dense forests without any marked growth. An oak may thus be twenty-five years old and yet have a height of only a few inches. If the shade-producing plants are removed these dwarfed trees will set up a renewed growth. For figures of such dwarfed trees see Beal, W. J.: Observations on the succession of plants in Northern Michigan. Annual report Mich. State Board Agriculture, 27: 74-78. 1888.

northern part of the county. It will probably be impossible ever to trace the history much farther than it had gone at the time of settlement.

THE LOWLAND SOCIETIES.

Under this heading will be briefly considered three groups of societies, the pond-swamp group, the lake-river group, and the spring-brook group. In the first I shall include those aquatic societies which are found in small ponds together with those marsh societies whose habitat is undrained swamps either on the margins of such ponds or elsewhere in swampy depressions. The second group will consist of the aquatic societies of the large lakes and of flowing water,—whether in creeks or larger streams,—together with marsh societies which occupy the drained marginal swamps along these lakes and streams, and also the moist ground societies of the river and creek flood plains. The third group will comprise the societies of the spring-brook and its margins. I have been unable to observe any variation in these lowland societies corresponding to variations in the nature of the soil. It seems to make no difference whether the soil be sand or clay, if it contain sufficient water to cause it to be classified as lowland, it will always bear certain types of vegetation. These various types depend, apparently, upon the *amount* of water so retained and upon the *nature* of the water as a solution.

1. *Definition and Distribution of the Lowland Societies.*—In the following paragraphs the definition and the distribution of the several lowland societies will be presented together. My study of the lowland has not been as thorough as that of the uplands and the discussion will not be as complete. The societies will be numbered consecutively in the same series as those of the upland.

a. *The Pond-Swamp Group.*—Throughout the county, but especially in the northern and northwestern part, depressions which reach below the water line are numerous. They vary in diameter from a few hundred feet to several miles, and their margins are of course sinuous and very irregular. They may be found on almost any sort of topography, but especially in morainic areas and in sand plains. In the former situation these deep hollows among high clay hills are often almost impossible to drain, even artificially. The great accumulation here in the form of peat, of which we shall speak later, has led cultivators to drain these swamps wherever practicable. Sometimes ditches for this purpose have to be twenty or thirty feet deep and take a sinuous course for several miles, following the depressions in the topography. Thus in morainic regions these swamps are naturally undrained; there is no circulation of water through them, it is lost almost entirely by evaporation.

In the sand plains these depressions occur principally along the margins. The margin of the Grand Rapids plain is in some places almost a continuous line of such swamps and ponds. They also occur out in the middle of the plain, notably so in the Green lake plain, south of the county line. These sandy basins are apparently as poorly drained as those in the clay; it is probable that the deeper clay holds the water. The vegetation is the same whether the basin is in sand or clay.

VI. The Chara-Nymphæa (Aquatic) Society.—Where these undrained

depressions are small, and at the same time deep enough to contain standing water throughout the year, we have a pond. The water is usually shallow and filled with aquatic growth. The presence of water prevents in some way,—perhaps by limiting the supply of oxygen,—the total decay of dead plant materials, and debris accumulates upon the bottom of such a pond, forming black peat. This may be intermixed with calcareous material from Chara[21] and from mollusc shells. The calcareous deposits may be quite pure, as sometimes in the larger ponds and lakes, so that they may be used for marl. Generally, however, an undrained swamp has a bottom of fine silt-like peat or muck, which,—being thoroughly saturated with water so as to furnish almost no support to a person or animal, and being of unknown depth,—gives to many ponds the name of bottomless. The vegetation of such a pond is characteristic. The white and yellow water lilies (Nymphæa and Nuphar), the alga Chara, which often forms great masses, the duckweeds (Lemna, Wolffia, Spirodela) and the bladderworts (Utricularia), are the predominant types throughout the county.

VII. The Sedge-Sphagnum-Tamarack (Bog) Society.—It is obvious that as an undrained pond is filled up by peat deposit its margin will be built out into the water. This process has been going on since the close of the ice age, and thus many ponds are surrounded by a broad belt of characteristic *undrained swamp* or *bog*. In many cases the pond has been entirely obliterated by this encroachment of the marsh upon the standing water. These marshes, whether they have a true pond in the center or not, always show a zonal arrangement of plants. Thus several distinct societies might be made out of what is here brought under one head. An admirable discussion of these zones of plant life in the Chicago area is presented by Cowles (loc cit.). The facts are the same in Kent county as there. Along the margin, in shallow water, are found sedges (Carex), the bulrush (Scirpus lacustris), Scirpus atrovirens, S. polyphyllus, the buck bean (Menyanthes), and the swamp cinquefoil (Potentilla palustris). Farther back these give way to the true peat-bog flora, comprising cotton grass (Eryophorum), peat moss (Sphagnum), leather leaf (Cassandra), Calapogon, Pogonia, Cypripedium candidum, C. spectabile, the tall blue-berry (Vaccinium corymbosum), cranberry, poison sumac (Rhus veninata), pitcher plant, sundew, Elodes campanulata, Woodsia, shrubby cinquefoil (Potentilla fruticosa) and the tamarack tree. The black spruce, which is common in such localities northward,[22] is rare here. In one extensive swamp crossed by the right of way of the Detroit, Grand Haven & Milwaukee railroad about five miles east of Grand Rapids, and bearing the name of Saddlebag, there were originally many of these trees. They were first practically all killed by burning. Now the swamp has been artificially drained and I think no spruces remain. The margins of the undrained swamp are often occupied by a characteristic margin flora of which the winter berry (Ilex verticillata), hardhack (Spiræa salicifolia and S. tomentosa), and the Osmundas (O. cinnamomea, O. Claytoniana, and O. regalis) are perhaps the most typical. Or the margins may have a vegetation resembling

[21] Davis has shown that Michigan marl is mainly from Chara. See Davis, C. A.: A contribution to the natural history of marl. Jour. Geol. 8: 485-497, 1900. Also: A second contribution to the natural history of marl. Jour. Geol. 9: 491, 1901.

[22] Whitford, H. N.: *loc. cit.* p. 314.

that of the dryer parts of the drained swamp, the elms, swamp oaks, asters, etc., forming a transition to the adjacent upland societies. Where the latter are of the type of IV and V, however, the transition zone is apt to be omitted. The margin flora just mentioned may be developed in such a case, or the swamp society may break off abruptly at the sandy slope which marks the original shore line of the pond from which the swamp has been formed.

b. *The Lake-River Group.*—The societies along the shores of the lakes and along the rivers and larger creeks are quite similar, no matter whether they be in sand or clay. Perhaps the wave currents of the large body of standing water and the better opportunity for saturation with oxygen and hence for oxidation, simulate the stream currents and prevent the existence of stagnant water conditions, whatever these may be. It is true also that most of the large lakes have outlets so that there is a constant, or at least intermittent changing of the water. In embayments and quiet places along the margins of such bodies of water the aquatics take on more or less the character of pond vegetation and the shores of such places are apt to develop the aspect of an undrained swamp. The vegetation here is often intermediate in character between that of the drained and of the undrained swamp.

VIII. The Potamogeton-Myriophyllum-Elodea (Aquatic) Society.—This occurs in lakes and the larger rivers. Besides species of the three genera mentioned it includes Vallisneria, Ceratophyllum, the water shield (Brasenia), water buttercup (Ranunculus aquatilis), and numerous green algæ, such as Cladophora, Spirogyra and Hydrodictyon.

IX. The Willow-Ash-Elm Society.—This occurs on the margins of lakes and rivers. The aquatic society (VIII) grades into the willow belt through a grass-arrowhead zone wherein wild rice is often predominant. In open places in the marginal willow thicket are often pickerel weed (Pontederia), cat-tail, Sparganium simplex and androcladum, and the like, or these may mingle farther out with the grasses and arrowheads. The sedge-bulrush zone is not nearly as pronounced here as in the case of the pond, though these plants occur often in great numbers. On the beach of Grand river, outside the willow zone, there is often a zone of rag weed (Ambrosia trifida) and other annuals.

But back of the willow margin, on the river and on the lake, we usually find a very characteristic drained swamp area. This is the richest in species of all our societies. It occurs along the margins of streams and lakes, but some of the finest examples of it are in the ancient channels of the glacial streams. The channel followed by the Grand Rapids & Indiana railroad from Grand Rapids to Ross was, at the time of settlement, almost one continuous stretch of drained swamp, although in some places there are patches of society VII marked by groups of tamarack. The same is true of the broad creek valleys in the northwestern part of the county. The vegetation here is a great complex of species, its *tout ensemble* remaining quite uniform but the component plants varying through a wide range. Only a few samples can be given. We may select the following: Black ash (Fraxinus Sambucifolia), elder (Sambucus Canadensis), Lobelia cardinalis, L. syphilitica, Polygonum lopathifolium, P. hydropiper, P. acre, P. dumetorm scandens, bittersweet (Solanum dulcamara), red osier (Cornus stolonifera), Epili-

bium coloratum, bugle-weed (Lycopus Virginicus), skull cap (Scutellaria), hedge nettle (Stachys), Solidago ulmifolia, panicled cornell (Cornus paniculata), sour-gum (Nyssa sylvatica), green brier (Smilax), arbor-vitæ, swamp oak (Quercus bicolor), red maple (Acer rubrum), slippery elm (Ulmus fulva), and alder (Alnus incana). The list might cover a page. Of course in any one place one will not find all of these plants, but they are pretty sure not to be far distant. Bugle weed is sure to be found everywhere. The Polygonums are the characteristic herb forms in the dryer parts of these swamps, and often in all parts, some ten or twelve species of this genus occurring there. Along the Rouge river, in the northern part of the county, the red maple is apt to be mingled with the willows in the margin zone.

V. The Basswood-Hackberry-Phlox-Lungwort (Flood Plain) Society.—This is the typical river flood-plain society. It contains many of the plants of society II. Here, as well as in society II, occur most of the spring flowering herbs, bloodroot (Sanguinaria), Trillium, Indian turnip (Arisæma), etc. The cork elm (Ulmus racemosa) is common, and the American elm frequent. Butternut and walnut (Juglans cinerea and J. nigra), the bur oak (Quercus macrocarpa), and the pig-nut hickory (Carya porcina), also occur here. Back from the lake or river this society merges gradually into the upland society which occupies the adjoining upland.

c. *The Spring-Brook Group.*—Here will be included a single society, that which forms ribbon-like stretches along the margins of the smaller brooks and broader patches on the springy hillsides, where the brooks have their sources. The little streams usually possess a well marked aquatic flora, which consists, however, of but few species. The algæ Vaucheria and Cladophora are found fastened to stones at the bottom, and the watercress (Nasturtium), together with water purslane (Ludwigia palustris), often forms great masses which well nigh stop the flow of water.

VI. The Lobelia-Chelone Society.—The trees of this society are either the same as of the upland through which the brook flows, or are like those of the drained swamp. But the herbs and shrubs which follow the brook are quite characteristic. Among these are the blue and red Lobelia (L. syphilitica and L. cardinalis), the turtle-head (Chelone glabra), the gentians (Gentiana Andrewsii and G. crinita), swamp milk-weed (Asclepias incarnata), beggar's tick (Bidens), tear-thumb (Polygonum arifolium and P. sagittatum), Aster puniceus, several Eupatoriums, alder (Alnus incana), and several low willows. Many of the plants found here also occur in the drained swamp society (IX), but they exhibit a better development here and are quite closely massed together in a narrow strip along the margin of the streams and in rather broad areas of springy ground at the stream's source, so that the society as a whole is quite distinct from IX.

2. *Generalizations on the Lowland Flora.*—From the possibility of such a classification of these lowland societies as the one just given, it seems probable that the main factor in determining their distribution is water. But the amount of water is practically the same in an undrained and in a drained swamp and on a brook margin; yet the floras are dissimilar, especially the first two. It has been suggested

that the great amount of organic materials in the solution of the undrained swamp may effect the plants physically or chemically and thus exclude those which occur in the drained swamp. If these substances effect the plants physically it must be through osmotic pressure. By this means a concentrated solution might withhold water from the plant. A few tests of the water from swamps whose flora was of the bog type seem to show that the osmotic pressure of the water is no greater than of that from a spring or river. Enough work along this line has not been done, however, to decide the question.

There remains the other suggestion, that the undrained swamp owes the peculiar character of its flora to the chemical nature of the soil solution. It may be lack of oxygen in the soil which shuts out the plants of the drained swamp. The question is to be solved by experiment, and not by observation. Perhaps, in the case of a brook, the more uniform flow of a solution of rather uniform constitution occasions the development in the margin of such a stream as different from that in a drained swamp. This question must also be attacked experimentally.

CONCLUSIONS.

From the present observations it appears that we are entitled to retain as a broad general hypothesis, the physiographic idea advanced by Cowles (loc. cit.), namely that physiography determines vegetation. But this hypothesis is not getting us very near to the ultimate factor upon which depends the distribution of the plant societies. The ultimate cause of all this varied vegetation must be something more particular, something which will affect the individual plant. For such a region as this, this *something* must exist in the nature of the soil; climatic factors cannot explain differences in such a small area; and the historical factor is broad and general like the physiographic one, and hence is not ultimate. That local differences in vegetation are due to soil factors has been as good as proved before this, and the proof is strengthened by the present study. The physiographic hypothesis explains how it is that various soils may be physically and chemically different. But after this is explained, the question with which we have to deal lies still untouched: What is it *in the nature of the soil which determines the distribution of our plant societies?*

Now, by "nature of the soil" we can denote two things, and only two, i. e., the *physical* nature and the *chemical* nature. But we have seen that neither of these can influence the plant *per se*. (See page 93). Either one of the features may, however, be effective through soil water. Water is the only feature of the soil which comes in direct connection with the vitality of the plant. The chemical nature of the soil may be effective through the nature of the dissolved substances which enter the plant, indirectly, through osmotic pressure. Its physical nature may be effective through the retention or non-retention in the soil of the water itself.

So far we may go *a priori*; beyond this tests must be made. The nature of the soil water from various soils in various positions must be carefully determined. From these determinations we shall know how much truth or falsity there is in the explanation here offered, that the nature of the soil water is not usually a decisive factor for such a region as this.

Also, by careful tests the ability of various soils to retain water must be determined, and these determinations recorded with the vegetation found growing where the tests were made. Thus, and thus only, can the hypothesis offered in the present paper be tested, i. e., the hypothesis that *the decisive factor in plant distribution over a small glaciated area is, in most cases, the moisture-retaining power of the soil.* Comparisons and observations can neither destroy this hypothesis nor establish it.

On the other hand, the present series of observations seems to show that the historic factor is a very important one in the distribution of the plant societies of Kent county, and the test of the hypothesis offered in this connection is to be obtained through observation and comparison, and through them alone; we cannot get the ice-sheet back and have the whole history worked out before our eyes.[23]

It may not come amiss to suggest some areas which it would be well to study for comparison with the present one. First, the study should be carried westward to Lake Michigan; along its shores we find much more primitive types of vegetation than anywhere in Kent county. Also, by this means the present area would be brought into better connection with that of Cowles' work. Secondly, an area should be studied in the center of the State and another bordering on Lake Huron or Lake St. Clair. With these at hand we might feel that we were free from the danger of drawing conclusions from a peculiar and exceptional area. Thirdly, there are needed studies and maps of several typical areas, scattered from the present one northward to Hudson's bay.

It is hoped that in the future such studies may be made and the results carefully mapped and published. Emphasis is here laid on the map, for by it alone can a satisfactory comparison be instituted. Photographs are apt to be too superficial to be of any accurate use, though they would undoubtedly be valuable in connection with the map.

I wish to thank Dr. H. C. Cowles, to whose writings I have had occasion to refer so often, for suggestions which have changed for me the whole aspect of the problem of plant distribution in this region, from that of a problem impossible—or at least hopeless—of solution, to that of one whose solution is apparently a question of time and of careful and accurate work.

[23] Similar conclusions to the ones here expressed have just been published. The paper appeared too late to be referred to in the main text. Bruncken, E.: Studies in plant distribution. 1. On the succession of forest types in the vicinity of Milwaukee. Bull. Wis. Nat. Hist. Society, 2:17-28, 1902.

MUSKEGON COUNTY.

Prof. C. D. McLouth of the Muskegon high school has put in a little of his summer time very intelligently and industriously in collecting data as to the soils as well as to flowing wells, and the deep wells which have recently been drilled. His assistance in the latter matters I would gratefully acknowledge while incorporating his help into my notes on the prospects of oil in that region given on a later page. But he has also prepared a nearly complete series of township maps, showing the distribution of the soils, and has helped Mr. Leverett in his work. I append his general notes.

SOME GENERAL REMARKS ON THE TOPOGRAPHY, SOILS, WATER SOURCES, FLORA, ETC., OF MUSKEGON COUNTY.

C. D. MCLOUTH.

Surface.—A large portion of the surface is a sand sheet covering nearly the whole county, the principal exceptions being portions of the townships of White River, Whitehall, Montague, Casnovia, Ravenna, and perhaps the northern part of Holton. A belt of this sand area some 10 miles wide and having its middle line approximately along the course of Muskegon river has the general appearance of a plain, but slopes considerably from the point where the river passes the county line to the shore of Lake Michigan, also it becomes shallower and apparently lower northward and southward from the river, that is, the river seems to run nearly along its deepest part. In Cedar Creek and Blue Lake townships sand dunes are conspicuous but of undetermined extent. Similar but slighter hills, knolls and ridges of sand occur in various parts.

The northwestern part of White River township presents a surface of clay approximately 100 feet above Lake Michigan. Southward and eastward loam and finally sand become the dominant soils. Casnovia, eastern Moorland and northern and eastern Ravenna constitute a hilly region in which morainic ridges are prominent, loamy soil abundant and deposits of boulders and gravel frequent. A moraine traced by Mr. Leverett winds northward through Fruitland township from near Muskegon through Whitehall and Montague, thence northwestward to the limit of the county.

Coast.—Along the coast the land height, exclusive of dunes, falls from an elevation of probably more than 100 feet at the northern end to nearly the level of the lake at the southern end. Clay is visible on the beach only at and near the northern limit. Cobblestones and gravel are noticeable in the vicinity of White lake. Sand, with a slight sprinkling of pebbles, is the feature along the remainder of the line. Dunes are highest at the south and form an unbroken line about one-

PINE STUMP, WATER LEVEL DEEP.

PINE STUMP, WATER LEVEL NEAR SURFACE.

C. D. McLouth, Photo.

half the entire distance northward, beyond which there are considerable portions along which the level land surface extends to the slope of the bluff. A mile or so below the northern line of the county the sand dunes begin to diminish gradually but rapidly, lying against the face of the clay bluff instead of upon the bluff, and within two miles north of the boundary no traces of dunes are to be found. Black and reddish magnetic sands are conspicuous in many places along the beach and are sometimes separated by action of the waves into layers an inch or more in thickness.

Lakes and Lakelets.—The lakes along the coast are of course confined within slopes corresponding in height and abruptness with the general land elevation previously mentioned. Little Black lake in the extreme southwest drains into Lake Michigan by a shallow ditch. It is practically level with the receiving lake and has been lowered somewhat by the ditch. The land rises away from its borders with very slight ascent except where low sand ridges seem to indicate former confines gradually moving toward the coast.

Wolf lake, in the interior, lies in the high sand plain near Muskegon river. Its banks are steep, entirely of sand, somewhat more than 30 feet above the water level, which is 67 feet above Lake Michigan. Carr lake or Five lakes, a few miles south and westward, consists of a series of shallow, receding ponds lying in hollows on the north margin of an undulating tract of sand that seems to be an area of old dunes. Twin lake, in Dalton township, lies but little below the general land level. Some of the lakelets northward have deeper basins.

Speculations on the Geological History.—Evidently in successive stages of recent times less and more of this region has been covered by Lake Michigan than at present. White lake, Duck lake, Muskegon lake, Lake harbor, are infillings of the lower valleys of the several streams that formerly flowed farther out to reach the great lake; this is shown by the fact that the bluffs now confining these lakes are exactly continuous with the bluffs now lining the valleys of the streams for miles inland. Numerous sand ridges, dunes and swampy tracts indicate former presence of water of considerable depth.

Various present conditions seem to indicate that the water is now or recently has been in quite rapid recession, considerably extending the land area. A large portion of Moorland with small portions of several adjacent townships is a recently reclaimed marsh (although considerably above Lake Michigan). Much of Sullivan township was a desolate swamp which extended into Fruitport and Norton townships, appearing to the eye as an unbroken plain and but a few feet above lake level at the coast.

In the southwestern corner of Fruitland township is a swampy tract extending back from the lake several miles. This swamp is bounded on the east by an irregular sand ridge reaching a height of 20 feet perhaps in places. Eastward from this ridge for something more than a mile extends a swamp that has been denuded of a fine growth of arbor vitæ and other trees. This second tract merges into higher land at the east, where it is more or less plainly demarked by low ridges and knolls of sand. This tract has been partially reclaimed and subjugated to the plow. Eastward still farther the land is mostly under cultivation, but

distinct traces of a swampy character remain. Again, in the eastern row of sections in Dalton township and extending for some distance into Cedar Creek is a low, moist, loamy and sandy area. The north branch of Bear creek runs along the western limit of this tract, its bed but little depressed below the general land surface. Close to the creek on the west rises an irregular dune-like ridge of sand clearly determining the southward direction of the stream. This ridge (which has been viewed only at a distance of about half a mile) seems to be the dune line of an older border of the lake. It is quite evident then that these several areas extending some twelve miles from the lake into the central part of the county are successive reclamations from the lake.

The high sand plain along Muskegon river is thought to have been a delta formation when the lake extended far inland. This is suggested by the fact that it seems to be highest near the present course of the river, sloping very gradually southward, northward and towards the present shore.

Springs and Wells.—Springs are of course numerous along the streams and in the hilly regions of the east and northwest. Near the lake shore many streams have cut deeply into the underlying clay and springs gush out from the banks many feet above the streams. In the so called delta region there is very little water found at the surface, but so far as known wells are not very deep, 20 feet often being sufficient to find good water. In the low and level tracts previously mentioned water may usually be found by very shallow digging. Wells from 4 to 10 feet deep are the rule. In Casnovia many wells are more than 100 feet deep and often water is not found even at a greater depth.

Flowing wells are quite common near the shore, ranging in depth from 35 feet at Montague to some 250 feet at the south line of the county.

Soils and Minerals.—The character of the soils has been suggested in various ways by what has preceded. The high sand plain covering most of Muskegon township and more or less of Egelston, Cedar Creek, Laketon, Norton, Dalton and Fruitland is a particularly barren region. Away from the immediate vicinity of Muskegon the settlers are very scattering; few signs of prosperity are visible in their homes; frequent deserted buildings and clearings show where the struggle to get a living and establish a home has been abandoned. In traveling over the region along nearly the whole course of the river in the county no public road has been found except at the head of the lake from which the stream could be viewed. Blue Lake township is a most desolate region, supporting the least population of any township in the county. The low and level regions before described are mostly of a sandy soil more or less mingled with clay and having clay or "hardpan" (the latter a ferruginous sandstone approaching bog ore) lying but a few inches or feet below the surface. The low sands are more or less dark and may be finer than the high sands, and are always moist because of the impervious material underlying. These lands are said to have been easily cleared of stumps because of the horizontal direction of the roots. The rolling lands of Casnovia and parts of Ravenna and Moorland, with the similar lands in the northwestern part, are perhaps altogether the most valuable for general farming.

A large deposit of magnetic sand within a few miles of Muskegon is

known to certain persons. At Twin lake the surveyor's compass is unreliable because of deflections. A deposit of diatomaceous earth lies somewhere in the northwestern part of Laketon township, probably not many chains distant from the coast.

Orchards and Other Crops.—Near the city considerable gardening and growing of small fruit is done even on the high sands. In Egelston township, between Wolf lake and Muskegon river, a man is surprisingly successful in raising melons on a high sand slope, using no fertilizer. Moorland has been famous for an immense production of peppermint oil, but low price has reduced the production to a small fraction of the former amount. Sugar beets are being grown with success on the swamp lands of Sullivan and Ravenna, the yield being high in tonnage and quite satisfactory in per cent of sugar. It is noticeable however that the acreage in beets yearly moves toward the loamy slopes bordering the swamp. Peach orchards in Casnovia township and in the vicinity of Whitehall village are thrifty and yield fine crops.

Native Flora.—Presumably the high sandy region was formerly occupied largely by pine and hemlock. The characteristic trees now are oaks, *Q. alba* and *Q. tinctoria.* These are usually of a scrubby character, but some good timber occurs. *Q. rubra* is scarce. *Pinus resinosa* is very scarce, only a few trees have been noted in Fruitland township. *Pinus Banksiana* is somewhat more common. *Pinus strobus* is seen everywhere, unless in the extreme east and northwest portions. Slocum's grove, occupying some half dozen sections adjacent in Casnovia, Moorland and Ravenna, is a splendid mixed forest containing perhaps 30 species of trees such as beech, maples, basswood, elms, oaks, hemlock, yellow birch.

On the moist low plains that have been recently cleared the characteristic tree growth seems to be the trembling aspen, *Populus tremuloides.* This seems to spring up quickly and profusely wherever such soil is left exposed.

The accompanying plate V shows the contrast between the roots of the pine in low places, where they have only a short way to go for water, and on the sand plains where they have to run down deep.

WASHTENAW COUNTY.

For some time the scientific departments of the State University have needed and asked for a topographic map of their neighborhood. Upon several occasions Prof. Russell has appeared before the legislature in behalf of such a topographic survey, not only of the neighborhood but of the State, and the following quotation from a letter from Prof. Spalding shows its importance in another department:

"I would like to reiterate and emphasize with all my power what you say regarding the necessity of a topographic map. This is so great a need with us in Ann Arbor that important work already begun will have to stop unless we can have the region mapped. I have already had some conversation with Prof. J. B. Davis, our professor of surveying, etc., in regard to a map of the Huron river at Ann Arbor. Some of my students have been constructing preliminary maps of some of the glacial lakes near here, and they serve for purposes of study to some extent, but they are not sufficiently accurate for a scientific piece of work and could not be

published. Prof. Reighard feels the same need; so does Prof. Runel. We must, by one means or another get truthful maps of the State just as soon as may be. You may be sure of the hearty coöperation of all of us on that score, for it is a 'long felt want.' The right way, as you suggest, is for the State to do its share towards paying for it and then get the U. S. Survey as soon as possible to go ahead."

In consequence I entered into an arrangement with the United States Geological Survey, a copy of which is found in another place, for a topographic survey which will nearly cover Washtenaw county and also portions of adjacent counties on the north, east and south, and will, I trust, be of use in many ways to the large number of students that come to the State University and Normal College, particularly in illustrating to them the utility of such a map, as well as the residents of the region.

When this map is finished I hope to arrange for a careful geological survey of the county. Mr. F. Leverett, Prof. Sherzer and Prof. Russell already have many notes on the surface geology and two deep wells recently put down, that at Milan and at the university, help to give us more exact knowledge of its deeper structure and mineral waters.

The samples preserved at the university of the well were put up wet and have so cemented that I have been able only to give a cursory examination. An abstract of my examination and correlation, combined with newspaper items, may not be useless, pending further details or in case the samples should be in any way destroyed, and will be found in connection with my discussion of the prospects for oil and gas in a later paragraph.

It is to be regretted that the university has not made all that it might in addition to science from this boring. The rate of increase of temperature, the magnetism excited by the earth in the casing, and the character of the mineral waters and their gases, are as worthy of study as the mere succession of the strata. This well might be an important part of the equipment of a geological laboratory.

LAPEER COUNTY.

This is one of the counties the rocks beneath which are probably rather monotonous, the sandstones and shales of the Marshall and Coldwater series. It is, however, one where we are very uncertain of the dips and where anticlinals suitable for the concentration of oil and gas may occur, so that every item of information by wells is of exact value.

Mr. J. J. Mason informs us that he put down a well at Columbiaville 1500 feet deep, the last 90 feet thereof being a brine-bearing sandstone, presumably the Berea. The well was plugged at 700 feet in order to use fresh water, which comes in probably from the Marshall at 300 to 400 feet depth.

Mr. F. B. Taylor began to work up the surface geology of this county in the summer of 1900. But his work is not entirely finished, and I cannot tell how soon we may be able to finish a report uniform with those of Vol. VII. I prefer, therefore, to publish here his preliminary report, which has already been given to the residents of the county through the courtesy of the Lapeer County Clarion, March 8 and 15, 1901.

SURFACE GEOLOGY OF LAPEER COUNTY, MICHIGAN

SUMMARY OF REPORT OF PROGRESS.

BY F. B. TAYLOR.

SURFACE GEOLOGY OF LAPEER COUNTY, MICHIGAN.

SUMMARY OF REPORT OF PROGRESS.

BY F. B. TAYLOR.

The field work upon the surface geology of Lapeer county is still in an incomplete state. The month of May, 1900, was given to this work and the results so far attained are summarized below.

Work upon a topographic map with contour intervals of ten feet is well advanced and is nearly complete for the southern two-thirds of the county. The northern third will require some further barometric work. Some of the rougher parts in the central portion of the county will need some further study, especially in Arcadia, Mayfield, Deerfield and Oregon townships. The extremes of surface relief range from about 750 feet above sea level on Flint river in northwestern Oregon township to about 1275 feet above sea level in southern Dryden and Metamora. The highest point of the region is in section 6 of Addison township, Oakland county, about three-fourths of a mile south of the county line. This point is close to 1300 feet above sea level. Belle river in northeastern Almont is down to about 780 feet above sea level, that is 200 feet above Lake Huron. The central part of the county has several clusters of rugged, irregular, steep-sided gravel hills. Dryden, Metamora and Hadley are mostly high and hilly, while the eastern border and Burnside, Burlington and Rich townships are mostly flat and close to the level of 850 feet above sea level. On sections 21 and 28 of Burnside is a sharp isolated hill commonly called Burnside mountain, which rises about 300 feet above the plain to the east. The topography of the county is characterized by a series of ridges and valleys. In the eastern half they trend southeast and northwest, but in the western half they run northeast and southwest.

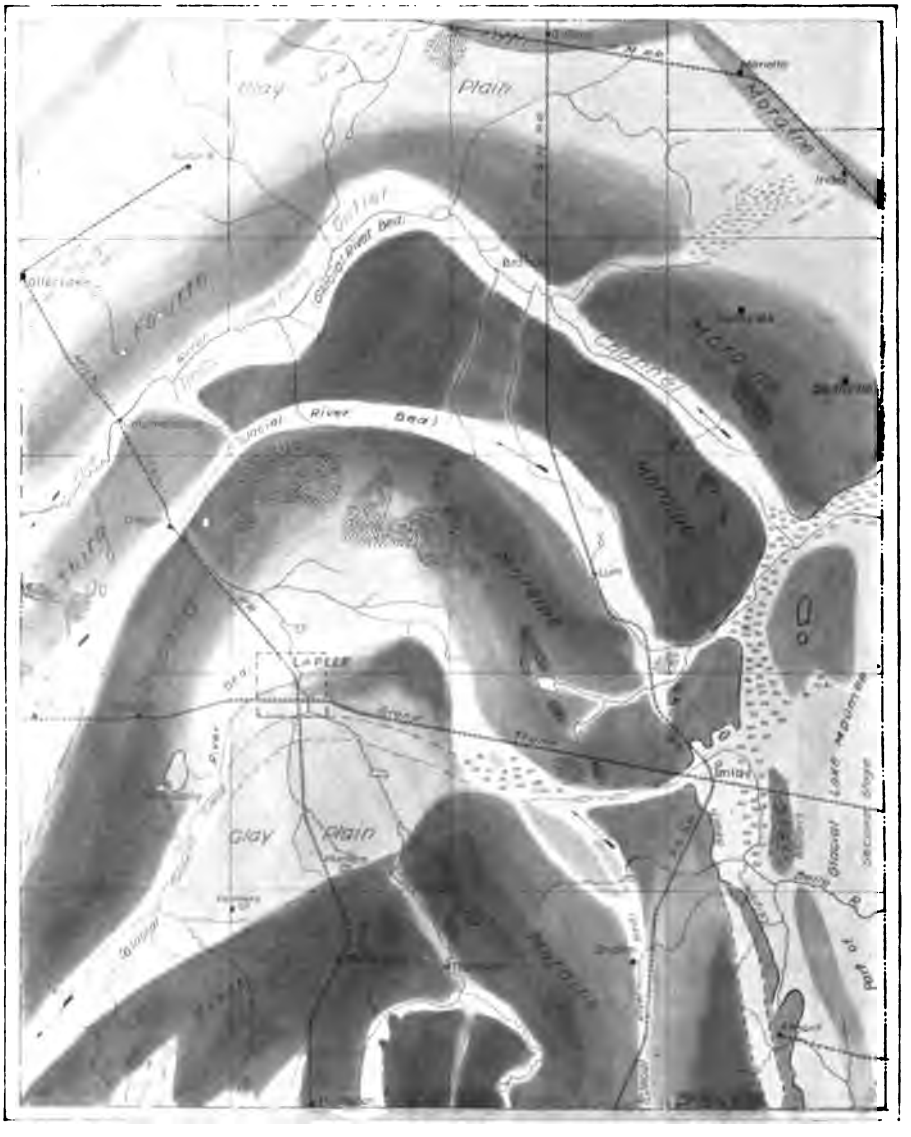
The bed rocks of Lapeer county are entirely covered by glacial drift, in most parts to a relatively great depth. So far as known they do not protrude at any point. The depth of the drift and the configuration of the buried rock surface beneath can be learned only as it is revealed in well borings and other excavations. Within the limits of Lapeer county there are so few such borings so far as learned which reach the rock surface that very little is known respecting it. In Dryden and Metamora townships, which comprise the highest parts of the county, the drift is known to be very thick, not less than 300 to 400 feet, and probably more. So far as learned, the drift does not appear to be much less than 100 feet deep in any part of the county.

The entire surface of the county is therefore composed of loose, unconsolidated sediments. By far the greater part of it is clay, but with a

considerable admixture of sand, gravel and stones, large and small. With but few exceptions the clay has stones and boulders scattered promiscuously through it; clay of this sort is called "boulder clay" or "till," and by well-drillers "hardpan," and is well recognized as a characteristic glacial deposit. It is the normal deposit of slowly-moving massive bodies or streams of ice, and its heterogeneous character readily distinguishes it from sediments laid down in water, whether still or in motion. Almost the whole of the great mass of softer sediments which covers the bed rocks of Lapeer county is composed of this boulder clay or till. But here and there through it and upon its surface are occasional beds of sand and gravel and bouldery places and sometimes beds of clay horizontally bedded in fine layers free from all coarser sediments. These distinctly classified sediments are the deposits of water, the coarser ones in running water and the finer ones in quiet or still water. They are all comprehended under the general term of *modified drift*, that which was laid down by the glacier without the intervention of water action being designated as *unmodified drift*. The entire mass of the drift deposits is made up of an exceedingly complex mingling of these two classes of sediments. But while the main constituent of the drift is boulder clay or till, almost every well or other deep excavation shows more or less extensive and irregular masses of modified drift, usually sand or gravel, embedded in or lying under the till. These more porous layers often become great reservoirs for the accumulation of rainwater, and when they lie in an inclined position and are overlain by an impervious bed of till they are likely to become the reservoirs for artesian wells and perennial springs. There are a number of artesian wells and springs of this kind in Almont township. Before the completion of the work, it is desirable to make some further collection and study of well records with a view of learning as much as possible concerning the conditions of natural water storage and supply.

The study of the surface features and deposits of the county is also well advanced. Incidentally to the study of the topography and the distribution of the different kinds of soil, much has been learned concerning the history of the development of the surface. Inasmuch as the topography and soil distribution of the county as we find them are almost entirely results of the particular processes by which the drift was originally fashioned, it seems desirable to present a brief sketch of the history of that development. The data for this sketch and for the map of the surface features which should go with it are nearly complete. The accompanying map (Plate IV) presents a rough sketch of these features so far as made out, but is lacking in accuracy of detail in some parts, especially in the northern and northwestern parts of the county.

The general facts required for this historical sketch are at hand and may be briefly summarized. As its maximum the continental ice sheet of the glacial period overspread the whole of Michigan, and it reached far to the south over Ohio and Indiana. At that time a solid mass of ice filled the basins of Lakes Michigan, Huron and Erie and covered all the intervening and surrounding country. Southern Michigan was then deeply buried under the ice to a depth measured perhaps by thousands rather than hundreds of feet. As it retreated northward by gradual melting, its margin frequently halted, probably periodically, and at each


Clay
Plain
Moraine
Moraine
Moraine

halt a more or less well defined ridge of drift was formed at and under the edge of the ice. These ridges are known as moraines. A numerous and intricate series of them has been traced out and mapped in Ohio and Indiana and southern Michigan, and their distribution shows that when Lapeer county first began to be uncovered by the retreating ice the glacier was still occupying the Saginaw valley and the basins of Lakes Huron and Erie. The glacier moved forward most rapidly in the valleys and lagged behind on the higher ground, with the result that the higher parts of the country were uncovered first as the ice retreated. The thumb of Michigan forms a broad ridge projecting northward between the Saginaw valley on the west and the valley of the St. Clair and Detroit rivers on the east. Lapeer county may be said to lie upon the basal portion of the thumb. As the glacier retreated, its margin formed in two great lobes, one projecting southward in the Detroit valley and the other in the Saginaw valley. Between these projecting lobes was a sharp re-entrant angle running northward on the intervening high ground into Lapeer county. Thus, through all the time that the ice-front was retreating across this country, the apex of the re-entrant angle between the lobes was within its area. Strong drainage usually issues from such angles in the glacier, and its magnitude is roughly proportioned to the magnitude of the lobes that bound it. In Lapeer county the rivers that drained the glacier were large and they made a strong impress upon the surface deposits. Although some further investigation will be required on the relation of the moraines and the associated drainage in the central, northwestern and northern parts of the county, enough is known to show that in its retreat northward the ice-front halted five times, the moraine of the last halt barely touching the northern fringe of the county. In each position, except the last or most northerly one, a river of considerable size flowed along the edge of the ice and was fed by streams issuing from the ice itself.

Moraines are not merely dumps of detritus falling from the steep front edge of the glacier, but are also largely accumulated upon and under the ice near its margin. Such a moraine forms a belt varying usually from two to five miles wide, though sometimes much wider. The first moraine formed in Lapeer county covers the western half of Dryden township, the southwest corner of Attica, the southeast corner of Lapeer, nearly all of Metamora and the southeast half of Hadley townships. This is a very hilly district and forms the highest part of the county. The earliest glacial river bed in the county is associated with this moraine and lies in Dryden and Metamora townships. It turns an entire semicircle, starting north across the county line south of Whigville and turning gradually around to west and south and passing out of the county about a mile and a half east of Thomas.

This river bed has peculiarities which are hard to explain. There is some evidence that it did not flow along the ice-front, but under the solid ice-mass itself, and that it issued from under the ice at a point about two miles south of the county line. The ice-front at the time of this moraine appears to have been a little south of the county line, and the relation of this channel to it remains for the present somewhat problematical.

The next later moraine in Lapeer county passes north through the

west half of Almont township, runs north-northwest through eastern Attica and central Arcadia, where it turns west across northern Mayfield and thence runs south-southwest through eastern Oregon, central Elba and northwestern Hadley townships. This moraine is quite irregular in character. It has a high rolling topography in southwestern Almont, is so weak as to be almost unrecognizable in southeastern Attica, but in northeastern Attica and in Arcadia and Mayfield it is very rugged and has many high, steep-sided knolls of gravel associated with it. In some parts it is chiefly made up of these.

The drainage at the time of this moraine went northward in eastern Dryden, northwest across Attica and, after crossing Lapeer in a course not yet clearly made out, it ran southwest up the course of Farmer's creek, across eastern Elba and central Hadley.

The next later or third moraine is a faint feature running north-northwest through central Almont and western Imlay and Goodland, becoming a strong feature in the latter township. Thence it passes northwest through North Branch to the northeast corner of Deerfield, where it turns southwest and, following the south side of Flint river, passes out of the county.

The drainage of this stage is not yet made out continuously. The long flat depression west of Almont suggests a line of drainage, but seems to lack specific characters of a river bed. It seems to fade away within three miles north and nothing representing a river bed appears until a point is reached about two miles northwest of Imlay City. Here a wide channel opens rather abruptly and runs northwest past Lum, King's Mills and north of Five Lakes. Beyond this its course is not yet made out, but there is a river course running across the center of Oregon township from northeast to southwest which is probably a part of the same. Between Almont and Imlay City it may be that a readvance of the ice filled up a channel that existed there and pinched it out.

The next and fourth moraine runs north-northwest through eastern Almont in very faint form and passes northward about a mile and a half east of Imlay City in broken fragments. In Goodland township it becomes a strong feature and turning northwest crosses southwestern Burnside, northeastern North Branch and southwestern Burlington townships. On the flat plains of Rich township it seems to have no representation. But in southwestern Rich and running southwest through central Marathon it is well developed along the north side of Flint river. This moraine and the two preceding ones are crowded together two or three miles south of Imlay City into a breadth of four or five miles.

At this stage the drainage took on a new relation. As the ice-front drew back to this position the water of Lake Maumee flowed in over a part of the ground uncovered and it found a free passage across a low divide in northern Goodland township and down Flint river. Thus an outlet for the lake was established instead of a river carrying only the drainage from the immediate ice-front. Lake Maumee was a lake which gathered in front of the receding margin of the continental glacier and it filled the valley of the Maumee river and had its principal outlet at Fort Wayne, Ind., and thence down the Wabash. One arm of this lake reached nearly to Cleveland in Ohio and another to Imlay City, Mich. But the

new outlet through Lapeer county did not carry the whole discharge, for the Fort Wayne outlet continued to be active. A beach composed of gravel and sand was made by the waves of this lake where it dashed upon its shore. This beach, known as the Leipsic beach, has been traced northward through Almont and Imlay townships to the northern part of Goodland, where the outlet narrowed up and began to flow as a river in which wave action was not so powerful. At Imlay City this beach is about 850 feet above sea level, but it declines somewhat southward. From the center of Goodland the river ran directly northwest to the southern part of Rich township, where it turned southwest and followed the course of Flint river, passing out of the county in the northwest part of Oregon township.

The last and fifth halt of the ice-front in Lapeer county made a moraine which barely touches the northern edge of the county. A faint morainic ridge passes north of Silverwood and runs west-southwest into the northwest part of Rich township. Another runs east and west north of Clifford and another runs southeast a little south of Marlette in Sanilac county. The course of this last one probably carries it across the northeast corner of Burnside township. But the northern townships of the county have not yet been fully studied.

So far as known, this moraine does not appear to have had a river along its front. This moraine and the preceding one are both rather faint in the northern part of the county and there is no well marked valley between them, but an almost level plain. All these moraines have well developed courses of transverse drainage, that is, at right angles to the course of the moraine and the ice border. The streams that made these seem to have flowed out from under the ice. Belle river follows one of these in Attica and Imlay townships to where it joins the lake outlet north of Imlay City. Mill river follows others through the second, third and fourth moraines across Attica and Goodland townships. Another runs south-southwest from northern Burnside to the lake outlet in North Branch. Flint river passes through one at Thornville, and again in eastern Oregon and Marathon it follows two others. There is a good one also in western Oregon running northwest to Flint river. This one has an esker in it. It some instances these lines of drainage appear to be associated with large accumulations of gravel and sand, which were laid down by the streams as they came from under the ice. The greatest gravel accumulations, however, such as those in the northwest part of Arcadia and in northern Mayfield, do not appear to be associated with such transverse river courses. The transverse courses through the fourth moraine seem to have carried off the drainage of the firth directly away from its front.

There was, presumably, a soil covering the rock surface of Lapeer county before the advent of the continental glacier. That was a soil of disintegration, produced by the decay of the rock surface as it lay in place. Probably most of that soil was swept away by the first advance of the ice, but a considerable portion of it may have been mixed in with the other ingredients which make up the till. So far, however, there has been no certain recognition of the preglacial soil.

The character and distribution of the present soil of Lapeer county is very intimately related to its glacial history. The drift which the

glacier left behind, with all its variety of topographic form and composition, has been the basis of soil formation. The weather, animal and vegetable life, and chemical action have all contributed to the final result. Mechanical forces of disintegration have resulted from frost and sunshine, from wind and running water, and from the action of both vegetable and animal life. Chemical decomposition results from oxidation and from the dissolving power of water aided by carbonic acid gas and the humic acid of decaying vegetation. The contribution of humus or decaying vegetation to the surface soil is perhaps the most efficient of natural agencies for its enrichment. Steep slopes and high ground generally are well drained and their principal sources of vegetable enrichment are derived from leaf mould and the decay of roots and fallen trees. But some part of these materials are always carried off in solution by surface streams to lower ground. Ponds and swamps, including especially in this county the old river beds, have poor drainage, and they receive a considerable contribution of enriching matter from the surrounding higher ground. A number of the ponds and swamps of Lapeer county contain deposits of marl and most of them contain more or less muck and peat, a few in considerable quantities.

The morainic areas of the county have for the greater part clay soils, and so have the flat till plains of the northern townships. There is, however, a considerable variety among these soils. They are heavier or lighter according to the proportion of clay they contain. The soil on the earliest or first moraine of the county comprising the high ground in the southern part, is in most parts rather more gravelly and sandy than the common run of the till in the other moraines and the soil is therefore a shade lighter. Some of this moraine, however, is purer clay and has a slightly heavier soil, notably in eastern Hadley and northwestern Dryden. The till plains of the northern and northeastern townships have in the main a still finer clay soil and are correspondingly heavier. Much of Rich and Burlington and Burnside, with the eastern parts of Goodland and Imlay, are of this heavier clay variety, sticky when wet and more or less inclined to harden on drying in the sun. There are sandy streaks, however, across Burnside township which contribute somewhat to ameliorate the toughness of the clay and turns it into sandy clay loam. Through the middle, southern and western parts of the county the clay soil is usually described locally as "clay loam."

There are a great number of knolls and scattering beds of glacial sands and gravels associated with the several moraines, and these of course have lighter soils. They are frequently devoted to fruit culture. Many gravel knolls are covered with orchards.

The old glacial river beds are mostly poorly drained. In consequence of this they are to a large extent swampy, although they all contain more or less sand and gravel in the form of bars formed by the currents of the glacial rivers. Some of these bars are flat and wide and furnish excellent light soil areas for small fruits.

The old lake outlet, or "Imlay Channel" as it is called, is mainly floored with muck and peat as far north as the north side of Goodland township. From that on it is partly occupied by sand bars to the bend in the south part of Rich township. Southwest from this there is an extensive sand plain bordering Flint river, narrowing at Columbiaville, but widen-

ing again below that and passing into Genesee county. This sand forms a very light, barren soil.

Dune sand is scarce, so far as seen, being found only in northwestern Mayfield and the adjacent part of Deerfield townships.

There are some large areas of muck (peat and celery) soil in Lapeer county, especially in the townships of the eastern and northern border. Some of these have been drained recently and are coming into use, notably those near Imlay City and along the course of Mill river in Goodland township. There are also many smaller areas in the central and western parts of the county.

Lapeer county has so far made but little progress in the development of industries based on its economic geological resources. These resources are, however, so far as now known, comparatively few. There is a considerable quantity of marl in the county and localities so far determined are shown upon the map. None of them, so far as learned, are of large enough extent to form a basis of cement works in the present stage of this industry. No beds have yet been found having an extent of over one hundred acres. Because of their present unavailability mainly, the marls found have not been tested thoroughly to determine their suitableness for cement. The largest swamps in the county, in the eastern and northeastern parts, appear not to yield marl. Marl was formerly burned for lime in several parts of the county, most notably in southwestern Hadley and southeastern North Branch townships.

Clay suitable for brick and tile manufacture may be found in several places, but so far as known none are now worked for these purposes. None, however, of the best quality and free from pebbles is known at present.

Gravel and sand are very generally scattered in patches over Lapeer county. For the greater part, however, it furnishes but indifferent road metal because it is too sandy. It remains loose and unpacked when put upon the roads. In many places the composition of the material is in large part too fine, and also in part too coarse. Such metal makes a road soft when new and rough after it has become settled or worn. The tendency of the sand to remain loose even where it does not appear to be too fine seems to be due chiefly to two causes: to the hardness of the pebbles and sand grains and to their roundness. Too few of the grains crush under the wheels to form any cementing material and the metal is generally very free from anything like clay as it comes from the pits. The grains are almost all of the hardest crystalline rock brought by the glacier from Canada, and their roundness and smoothness is such that they will not knit together and pack without the aid of some cementing material. Clay is sometimes put on sandy roads for this purpose, but this method, while it works well in many cases, is too commonly overdone. Too much clay is used to attain the best results. By a little judicious screening of the gravel and a proper use of clay for cementation, there is every reason to believe that the generally too sandy road metal of the county can be utilized to good advantage.

It may be remarked again in closing that this sketch of the surface geology of Lapeer county is prepared upon an incomplete basis of observation. Three or four weeks more ought to be given to field work before the final report is written.

ECONOMIC GEOLOGY.

ECONOMIC GEOLOGY.

The special subjects or heads under which geological research may best be grouped are of two kinds. Either they represent business interests, and the facts grouped under each head relate to the raw material or materials of some industry; an illustration are the papers on clay, coal and marl, all materials for the cement business, which are appearing in our volume VIII; or on the other hand it may be some more purely scientific question, upon which the facts grouped together throw light.

In regard to general relations of geology, especially of this State, to the business world I shall beg leave to submit a lecture given before the Field Columbian Museum* November 2, 1901, though the style is somewhat informal and I cannot well reproduce the accompanying lantern slides.

THE ECONOMIC GEOLOGY OF MICHIGAN IN ITS RELATION TO THE BUSINESS WORLD.

RAW MATERIAL.

It gives me great pleasure to represent the State from whose gypsum quarries comes one-third of the product of the United States, which not only furnishes most of your wall plaster, kalsomine, adamant and similar wall finishes, and magnificent slabs of oriental alabaster (Michigan is east of Chicago), but particularly the material of that White City which embodied in a beautiful dream the aspiration for beauty, the abounding liberality, the indomitable energy, the civic pride, and capacity for harmonious work which characterize this city of which you are proud to be citizens, in order to tell you something of its other treasures of raw materials which have supplied and will largely supply the matter for your work.

For economic geology is but the science of raw materials, the real or ultimate raw materials, upon which no work has been done. Such materials are always parts of the earth's crust. In common parlance, many things are called raw materials which are raw materials for one industry perhaps, but are the finished product of another. Iron ore may be a raw material from the point of view of the Pennsylvania blast furnace man, but it is the finished product of the Michigan miner, just as much so as the pigiron turned out by the furnace men, which goes on from hand to

* Reprinted in the Michigan Miner for Dec. 1901.

hand, or rather from machine to machine, issuing as the finished watch spring, only to become at once raw material for the watch manufacturer.

Now, the business world is concerned with material wealth, which is labor incarnate in matter. Energy, ability and wisdom become matters of business, objects of exchange as well as desire, only when they are employed upon and embodied in matter. Dirt has been said to be matter out of place. Raw material is matter out of use.

LOCATION.

Sometimes all that is required to bring the raw material into use is change of location. The strawberries which rot in Michigan beds would find a use fast enough in Chicago streets. Some of the sand piled high on Huron county beaches is worth over a dollar a ton placed at the bottom of a copper-smelting furnace. The waste sands from stamping the rock to get out copper are of no use in furnace bottoms, but, mixed with a little asphalt, make the best of paving blocks. A good gravel bed, such as that at Mecosta, well placed for road mending or railroad ballast may really be worth more per cubic yard than the golden gravels of the Yukon, the difference depending on the fact that the latter are hard to reach.

The value of an article in any market is then normally very closely dependent on the amount and quality of labor required to get to market the part of the supply needed that costs most.

The value of the raw material is proportionate to the advantage which it may have, in that it can be put into market and in shape for it with less labor.

Please note, for instance, how the copper mines of Michigan are chiefly grouped close to two great gaps in the range. Is this because the copper is bunched there exclusively? It is hardly likely. Is it accident? No, it is almost certainly due largely to the relative ease of transportation and discovery. The new railroad south from Houghton is partly the effect but partly the cause of the opening up of a new tract of copper-producing land.

These two processes just mentioned, putting the raw material where it is wanted and putting it in the shape it is wanted, correspond to the two great divisions of business, commerce and manufactures. The railroad and the commercial traveler are busy putting matter where it is wanted, —the mill and the manufacturer mold it into the required shape.

Let us then begin by looking at the advantage which Michigan has from a commercial point of view, in the ease in which transportation to market may be obtained. Studies of location are, as may be seen from what has been said, a very important part of the study of economic geology.

One of the points of vantage is our nearness to Chicago, and a word as to the commanding position of Chicago itself may be allowed. The great cities of the world are generally found in geologic basins, and very frequently the basin takes its name from the city. Rome, Vienna, Paris and London, for examples, have geologic basins named after them. Such a disposition of the geologic strata makes some city near their center the natural meeting point for the later stages of manufacture and mart of trade for different materials. Now, Chicago may be treated as the center of a vaster basin than any of those mentioned, which extends

from the coal mines of Pittsburg to the upturned strata of the Garden of the Gods in Colorado, and from the mines of Michigan to the Gulf of Mexico, the whole Mississippi valley, in fact. Michigan is also near to other great open markets, not only to Chicago and Detroit, but to Buffalo, Cleveland and Duluth as well.

WATER FACILITIES.

Not only is she near them, but she has cheap water transportation to them. Nowhere else in the world is there so great an extent of fresh water coast line (dotted with fisheries of value). Few states of the Union have so much water line of any kind. Not only is it cleft into two peninsulas (and outlying islands which amount to some 200,000 acres more), but by Saginaw bay and the so called Saginaw river the level of the Great Lakes reaches the center of the coal basin and the geologic center of the State. Moreover, the whole west shore of the State is lined with lakes, big and little, which the mere cutting of a sand-bar transforms into first-class harbors. The geological explanation of these lakes is full of interest. The land in which the basins filled by the Great Lakes lie is rising, but not equally. The farther north, the greater the rise, at the rate of about 0.4 foot per 100 years per 100 miles toward the north-northeast.

The result of this lift is evidently a tilting of the basin, so that while the water is leaving the northeastern part all the time it is backing up on the shore in the southwestern. This would naturally back the water of the lakes up the river valleys, and the Chicago outlet is but an anticipation of the course of nature. The Saginaw, the course of which is exactly against the direction of the uplift, is a good example of a backed-up stream, though the effect there has not been great. On the west shore the prevailing west winds and the lake current combine to throw sand-bars across the mouths of the drowned river valleys and convert them into lakes, and thus we have every stream of the west shore ending in a lake. This enables the direction of tilting and the line between the part where the water is retiring and that where it is gaining to be fixed quite nearly, for if we pass a line from the outlet at Port Huron to the northwest between Traverse City and Frankfort, then every stream to the south empties into a lake which is only the flooded part of its own lower valley. On the other hand, the streams to the northeast of this line come into the lake on the run, with water-powers close to their mouths, as at Alpena, Cheboygan, Elk Rapids, etc., thus showing that the lake has been getting away from them.

INTERRELATION OF RAW MATERIALS.

We have also to consider, in estimating the value of raw materials, not merely their location relative to great marts of consumption, but also relative to other raw materials, for there are but few finished products into which only raw material has gone. Take, for instance, the manufacture of beet sugar, of which Michigan will produce this year between one and two hundred million pounds. Those who are not specially interested perhaps think of the matter as one mainly of the climate and soil for sugar beets, but that is not the whole of the story. Besides sugar beets, water is needed, good water and plenty of it, without much organic

matter and without salt. Only the other day I was consulted as to a supply of water for the Bad Axe beet sugar factory, and I have been informed that a doubt as to the quality of the water delayed the building of a beet sugar factory at Saginaw for years. Not only is water needed, but coal or other fuel to evaporate the water after it has soaked the sugar out from the beets; for instance, the presence at hand of slack as a cheap fuel is an important advantage of the Bay City factories, and the possibility of coal in the neighborhood, in fact right beneath the factory, may mean a good deal to the Lansing factory in the coming days of severe competition. Not only is the coal needed to boil down the juice, but limestone to clarify it, and that of a very high grade with less than two per cent of impurities if possible. Perhaps this one illustration will be enough to make clear to you the importance of the relation of locations in the study of raw materials. It is probably this principle that leads the center of a geologic basin to become a center of industry, because around it the various kinds of materials are arranged, and in it they meet for their mutual edification and improvement.

SAGINAW THE CENTER OF ATTRACTION.

Now, we find as a striking feature of the geology of lower Michigan a basin-like arrangement of the beds.*

A brilliant French writer, with that fondness for antithesis so characteristic of French style, has remarked that the rocks of France are arranged around two poles—the positive or attractive pole, toward which the rocks dip, toward which the streams of water flow, and, beside these material streams, streams of youth and intelligence, I need hardly name. To a Frenchman what can be the attractive pole of France but Paris? The other pole from which the rock strata dip is a rough mountainous region, repellant except to those who rejoice in wild scenery or who have been fascinated by architectural studies. This region of primitive rocks, where the original crust of the earth stands nakedly forth except as partially swathed in the debris of extinct volcanoes, is the rugged region of the Auvergne, culminating in Mont Doré and the Mont du Cantal. Around Paris and the Cantal curves in a great figure eight the band of Jurassic strata, while younger beds surround Paris and older ones are found in the Cantal curve.

This antithesis may without forcing be applied to the State of Michigan; but the geological center of attraction is neither Detroit nor Lansing, but Saginaw. This is geologically the center and attractive point of the State, and a geologist must prophecy a brilliant future for Saginaw and Bay City, which have the advantage of Chicago on a smaller scale. Toward it flow the rivers from all directions. Around it lies the coal basin, the youngest of the consolidated formations. The encircling strata of lower rocks all around dip toward it; and, turning to the most recent deposits, successively older and older beach lines encircle it, and then terminal moraines of the ice sheet.

The great figure eight made by the Jurassic strata in France must be replaced for Michigan by the Great Lakes, which unite and divide the two peninsulas.

* See Michigan Moderator, October, 1899. Also Plate IX.

The negative pole, the rugged protrusion of oldest rocks from which the strata dip and the streams flow, we find in the Huron mountains northwest of Marquette.

There are a number of other ways in which these two poles may be contrasted. The one is the highest land of the State, the other the Saginaw valley, the lowest large area. The one is surrounded by mines of iron and copper and is relatively devoid of farms. The other has mines of coal and is a fertile valley. The one pole is and will be comparatively unpopulated, the other is or will be densely populated.

Michigan may also very handily be compared to two hands. The right hand is the Lower Peninsula, fat with fertility. The Saginaw valley is the hollow palm upturned, receiving blessings from the skies. The likeness is so plain that the district of Huron, Sanilac and Tuscola counties has long been known as the Thumb. The overhanging and projecting cliffs of the Point Aux Barques may pass for the Thumb-nail. Leelanau county we may then call the little finger.

The Upper Peninsula may then be taken as the left hand, which will be leaner, with bones and sinews of rock far more prominent, and of this hand Keweenaw Point may be taken as the thumb.

The two hands taken together contain almost all the resources necessary for man, and mutually complement each other.

UNION OF INDUSTRIES.

One striking instance of correlation in industries and in raw material has been of the greatest importance in Michigan. I refer to the union of lumber and salt. In the manufacture of lumber there was a vast amount of waste wood and saw-dust which had to be burned to be got rid of, which indeed is burned today in some places. But fortunately almost anywhere in the Lower Peninsula of Michigan one can by drilling find either rock salt or a strong brine for salt manufacture. In the former case they pump down water to dissolve the rock salt so that in both cases they have to evaporate the brine, and for this the waste heat from burning the saw mill refuse was used. When the pine was cut and the saw mills of the Saginaw river began to move or burn up without rebuilding, it was thought that time had struck the knell of the salt industry. But instead of that the hour had struck to awake the black giant coal, which all this time had been lying low and saying nothing, to take up the task. And now in the Saginaw valley, whenever they have a little waste heat or coal, at the power plant of the electric road, at the glass works or at the dump of the mines, they can always turn it to use in making salt.

Of all the raw materials, those which supply power to do a man's work for him are of the most value, not only in themselves, but in their correlative raising the value of almost every other adjacent material. Two of them we have just mentioned—wood and coal. Others are water-power, wind, peat, oil and gas. These materials do not have the generation of power as their sole use; but if, as we have said, wealth is labor incarnate in matter, it is obvious that anything which can replace or multiply labor is of the widest economic importance.

WATER-POWER.

Of all these sources of power, water-power is probably the most permanent, though if we sacrifice our wood too recklessly we may also injure our water-power resources.

It is not possible to go into details regarding the water power of the State, for which I must refer to the writings of Robert E. Horton,* but one or two salient facts may be noted. One of these, the location of water-powers near the mouths of streams northeast of the tilting axis, has been mentioned. Another is the abundance of lakes upon the highlands of the Lower Peninsula, which serve to steady the flow of the streams. The Great Lakes formerly stood 100 to 200 feet higher than today. As they retired they left the old lake bottoms, around Detroit and Saginaw, for instance, as nearly smooth plains, while above their former extent we have a region which was the dumping ground of three glacier arms, one of which came down Lake Michigan, one through Lakes Huron and Erie into Ohio, and a relatively shorter one followed the Saginaw bay. This higher region is studded with lakes and swamps, and near the boundary of the two regions there is an especially well-marked water-power belt, on which Adrian, Tecumseh, Ypsilanti, Rochester, Owosso, Alma, Mt. Pleasant, and a host of other thriving little manufacturing towns are springing up.

This line is not only one of river water-power, but also one where we are especially likely to find flowing wells. Though one does not often think of them as sources of power, they are, for they save the work employed in pumping or the cost of a windmill, and when they will run a hydraulic ram, or without it throw water all over the house, they are a commercial asset of value.

The flowing wells just referred to come from the drift, and are from strata of gravel, etc., having their sources toward the highland region and following the slope of the country down to the lake. But, beside these wells, there are many from the rock.

The structure of the State being that of a synclinal or basin, wherever a boring can tap a porous bed which takes in water at some higher level we are likely to have flowing wells. This was the case over most of the Saginaw valley and in the valleys nearly all the way back to Hillsdale, as at Lansing. Along the shore of the Lower Peninsula, too, with but few exceptions, flowing wells may be obtained. In the Upper Peninsula, along the whole of Lake Michigan from Menominee to Drummond's Island, wells with a strong head may be obtained. The Lake Superior shore from Keweenaw Point west should also yield artesian wells.

The temptation to digress and discuss the water supplies of farms and cities, the great advantage which the Upper Peninsula has in its soft waters, the cost of the hard water in laundry bills and soap, and the distribution of hard and soft waters through the State, must be resisted, for power is the subject in hand just now. I will merely remark that manufacturers and promoters have made trips from Chicago and Detroit to Lansing just to talk over this one matter with me.

Returning to water-power proper, I would remind you that in connection with electricity water-power is to be of increasing importance. A

* U. S. G. S., Water Supply papers No. 30, 48, 49 and the Michigan Engineer for 1901.

great dam at Allegan has just been put in from which it is planned to realize 3,000 horse-power. Another is in preparation. Thunder Bay river furnishes several hundred and could furnish perhaps 2,000 or 3,000 horse-power at several different points. But the greatest water-powers of the State are yet undeveloped. The Au Sable, Au Gres and Rifle have numerous lakes and considerable flow all the year and magnificent water-powers untouched. In the Upper Peninsula there are still more. Lake Gogebic sends fine power past the Victoria mine, and the Ontonagon river has a large valley to the south of the Copper Range, through which it forces itself with a rapid flow.

The Dead river near Marquette furnishes light to all the town at a nominal cost, but it has 850 feet of fall in 10 miles and could do every stitch of work done in the town. The Sturgeon falls help run the mines of Iron Mountain, and, though I shall not pretend to list the Michigamme, Tahquamenon and all the other powers, yet I could not be pardoned if I forgot the "Soo" with its 18 feet of fall and all Lake Superior behind, where the carbide for your bicycle light is manufactured.

In air power Michigan has no special advantage.

WEALTH IN WOOD.

The wealth of Michigan in wood is well known, and, though the forests of pine that were thought inexhaustible are well nigh exhausted, there is yet a great deal of hardwood left, the raw material of the furniture manufacturer and also of the charcoal man; 160,000 tons of charcoal iron are made in the State.

The great wealth in wood in kind and quantity is due to the range of climate and range of soil. The hardwood belts are characteristic of the glacial moraines. The use of waste wood as fuel has been already mentioned. The next source of fuel (peat) may be considered a mixture of the two previous (wood and water). We have used our own peat bogs to grow peppermint and celery, and the peat itself for nursery packing, etc., but until recently no serious attempt has been made to use it as fuel.

It is so largely water that it cannot be an economical fuel unless we can arrange to have it handled, compressed and dried by machinery, and make the peat itself do the work. If that can be arranged there are millions of tons awaiting development, for there are vast peat bogs in both peninsulas and a company has been formed to experiment.

If wood is the father and water the mother of peat, coal is its child, and there has been no more important raw material than this. The coal basin of Michigan covers at least 7,000 square miles, and I have estimated that 8,000,000,000 tons await development, but it has been backward in developing and has lain dormant under a sheet of glacial deposits and a blanket of lake deposits while the fields further south and better exposed were opening up.

As late as 1895, when I first visited Saginaw and urged the development of the coal deposits, there were but a few thousand tons produced in the whole State, which today is producing a million tons a year of frequently excellent bituminous coal. It has spread to Nebraska and the Dakotas, and is one of the factors to be reckoned with in the future development of every material in the State.

OIL AND GAS.

Oil and gas we cannot count a Michigan resource. There is a small refinery at Port Huron, but thousands of dollars are spent almost every year in boring with no commercial results. We have several oil and gas-bearing strata underlying the State,—the Berea Grit, which is a famous Pennsylvania sand; the lower Devonian beds, which have yielded such rich results in western Ontario; the Trenton, which is the famous Ohio oil rock,—but the basin-like structure does not seem to be favorable to concentration into gushers. And yet I live in hopes that some day some subordinate pucker of value will be found.*

IRON.

Not only does man want power to do his work for him, but he wants tools to do it with, and that means iron, the framework of our whole industrial system. I do not need to tell you that Michigan is one of the greatest iron producers in the world, that the tonnage which pours through the canal at the "Soo," making it surpass the Suez of the old world, is largely iron ore. In 1900 3,457,522 tons from the Marquette range, 2,875,295 tons from the Gogebic range, 1,665,820 tons from the Vermillion range, 7,809,535 tons from the Mesabi range, besides 3,261,221 from the Menominee range which does not go through that portal, or nearly 10,000,000 tons of iron, are produced in Michigan.

These facts are familiar, but the course of the iron ore trade in the past 10 years illustrates some principles of wider application to raw materials, so that I will go into some detail.

Early in the nineties iron ore from a new range appeared in the Cleveland market, and caused consternation in the heart of Michigan ore producers. It was the Mesabi range of Minnesota. Here iron ore could be mined under conditions than which nothing better could be desired, except as to climate. It was 13 below zero when I visited the range in March, 1895. The ore bodies were soft so that they often could be scooped up with a steam shovel and put on to the cars directly. They were generally quite flat, and covered with only a light covering of soil or unconsolidated glacial deposits. Under such circumstances the cost of ore was hardly more than of railroad ballast, and the miners of Michigan, mining in hard ore bodies, mainly standing vertically and with the cream already from the top, hardly saw where they were coming out. (The iron ore of Michigan I may say comes from a process of leaching and is gathered in lenticular irregular pockets in the oldest stratified formations of which we have any certain knowledge.) Indeed, as I was traveling in the rigors of a northern winter in the hard times of 1893, one-third only of the chimneys of Iron Mountain and Ishpeming were smoking. However, it was found gradually that the soft friable ores of the Mesabi needed some old range hard ore to make them work well in the furnace. Another thing had happened also. The hard times had taken the heart entirely out of the Duluth boomers, and left them an easy prey to the octopus.

Some years before the spare dollars of some of the Standard Oil men had been invested on the Gogebic range. As usual in people who go

* See article on prospects for oil and gas, below.

outside their business, in some cases they got pretty badly bitten, but they are stayers, and once in they did not let go, but added property until they had a strong interest in the Gogebic range, though how much they paid for it I do not know.

Through their interest there they were led on to other iron ranges, especially the new Mesabi, and, to make a long story short, by 1895 it came to be recognized that there were two great interests in the Mesabi range, each of these controlling a railroad to the lake ports—the Duluth & Iron Range and the Duluth, Mesabi & Northern. Each of these interests had properties on the other ranges which it would not pay them to let go to rack and ruin, and it was soon discovered that the two new Minnesota ranges, the Mesabi and Vermillion, were not destined to deal death and destruction to Michigan iron interests, for it was also discovered to their sorrow by the independent ore producers of these ranges that these two great interests did not care a nickel whether they made their profits in the railroad corporation or the mining corporation, and they accordingly fixed the rates for ore so that only just so much ore should be mined as suited them. If that left a very small margin of profit for outsiders, and it generally did, they were usually allowed to sell out when they got tired.

A fight followed for new railroads, and for state regulation of the ore rates in the Minnesota legislature, which is outside the scope of my paper. It did not break the grasp of the larger interests on the situation materially, and the next step in a great industrial evolution followed in the acquisition by the Rockefeller interests of an ore-carrying fleet. This brought all the work from the ore in the ground to the open ore market at Cleveland under one control. Up to this time the transportation of the ore had been a matter of bargain and sale, and close competition with widely fluctuating rates, depending not merely on the activity of the iron trade and the demand for iron ore, but also the movement of corn and wheat from Duluth, etc. But now from the mine to Cleveland came under one control. Simultaneously from the other end consolidation had gone or went on, rolling mill with blast furnace and steel plant and blast furnace with railroad, until the complete consolidation was only a question of time. This has just followed, and whereas we had seven independent interests and three open markets on the way from the raw material in the ground to the finished rail ready for the track, (towit:

Miner,
Railroad,
Boat.
Cleveland open market for ore—
Railroad,
Blast furnace.
Pittsburg and Ohio market for pig iron—
Rolling mill.
Open market for rails—
Railroad.)

Now we have but one—the United States Steel Company, or if, as is commonly reported, the Pennsylvania railroad controls the Republic Steel

Company, in that case the consumer owns practically the raw material and there is no open market. I do not mean that these two concerns control the steel industries. There are a number of other plants, but more and more each interest in self-protection is found to own or control its own iron mines and intermediate links. It is easy to see the advantages of the system. The great corporation can take the ore more easily mined first. It does not feel the anxiety of the small private owner, that he shall see the reward of his piece of ore in his lifetime, that often gluts the market. Whereas in the old days, the mines mined all they could to reduce expenses and production, and fought the ore carriers for low freights, and one year made lots of money and the next were in the hole, and the same thing was true of the blast furnace man in his field, now, given the amount of rails needed, the ore to be mined can be adjusted accordingly. In other words, the speculative element is eliminated from business and concentrated in Wall street fluctuations in prices of steel stocks. Moreover, the great corporation can afford to do what a small one cannot. It can, for instance, and does execute private geological surveys that put those of the State to shame. A small owner could not do that,—it would not pay him. It can study and experiment on minor economies which may be worth while on account of the large scale of its operations as a private individual cannot. A very important item of saving in the Rockefeller system is the building of huge ore carriers of 5,000 tons and over. The fitting together of the various links is also better, until, as Dr. Hulst tells me, the ore is raised and handled but twice from the mine in the far north to the pig-iron of Pittsburg. Machinery and gravity do the rest.

Sometimes it is said that but one profit is required instead of seven, but that depends upon whether the combination is capitalized at less than the units.

Now, I wish to call your particular attention to the difficulty of entering into competition with such an anaconda of industries except along the whole line.

Suppose I find and start an iron mine. What chance do I stand if the railroad belongs to my rivals? Even suppose that my mine is right by the lake, still I must trust to shipping and be dependent on the shipowner for reasonable rates,—and then whither am I to ship it? I must find an independent ironmaster to smelt my iron and turn it into rails. And at the other end, if I want to go into the iron business, there is no use in erecting a blast furnace unless somebody at hand will buy my pig iron, or starting a rolling mill unless some one will use my iron plates. Moreover, I must be sure that I can get pig iron as reasonably as any one, and the blast furnace that makes the pig iron must be able to see its way clear to a supply of ore. And just here is the reason why Michigan, producing 8,400,000 tons of iron ore, produces 163,712 tons (less than one-half per cent as much) iron, and this charcoal iron for which our forests are furnishing the fuel at tremendous cost. For why should not iron be made in the State, say at Bay City? Coal is handy, the best of limestone is handy, the ore is nearer and a good deal of iron is used, and more will be, in shipbuilding, etc., boilers, etc., right in the district, and I know of capitalists who pine for the chance to put in the money. There is

just one reason. We are too late. A modern plant for the manufacture of iron and steel costs hundreds of thousands of dollars, and no people are going to put in their money unless they can be sure of suitable supplies of ores, and most of the available known ore is controlled by the United States Steel Company or other manufacturing plants. It must not be forgotten that with the growth of industries into large units the scrutiny of the quality of the raw materials becomes ever more severe. If you need a few sacks of cement for your cellar floor you do not test it, for it would not pay, but depend upon the reputation of the brand, nor do you have your coal analyzed before placing your winter order, though very likely it might pay, but if you were to have a $10,000 order of the one or the other you would not be wise if you did not. A difference of 1 or 2 per cent in ash would pay for a gross of coal analyses. So, for instance, in iron the percentage of phosphorus is studied with the greatest care. If it runs over one-tenth of 1 per cent it ceases to be Bessemer ore suited for steel production and it makes a great difference in the price of the ore, and the hundredths of a per cent are watched with jealous care. Now, one great advantage of our better Michigan iron mines is their low per cent of phosphorus, though analyses are going on all the time, for even these minute percentages are not distributed at random, but show that their distribution is affected by a leaching action. This scrutiny is felt all over the line, and the strain upon the chemist and the economic geologist is ever greater. It is not merely where is iron ore, where is limestone, where is coal, but where is the biggest and the best (not over 2 per cent of impurities) and the handiest deposit. But the last factor, that of accessibility, becomes day by day less important as roads and railroads multiply, especially in this State, where, as we have said, every part is equally accessible to large operations.

Before leaving the iron business let me say that while the consolidations which led up to the organization of the United States Steel Company seem to me to be distinct steps of progress in the orderly conduct of business, in such a combination, as in the combination of molecules in a crystal of alum, it is possible that a great deal of water is taken into the arrangement, and the heat of adversity is likely to drive off this water of consolidation, respectively crystallization, even if the whole arrangement does not deliquesce.

COPPER.

Leaving now iron, the sinew of Industry, we turn to copper, which furnishes her nerves. Up to 1876 the Michigan mines often furnished nearly 90 per cent of the total output of the United States. Of late years, however, the growth of Michigan's output has not kept pace with that of the western, until now our production of about 150,000,000 pounds (155,845,786 in 1899, 144,227,340 in 1900) is but a quarter of that of the United States. Yet the copper of Michigan occupies a unique position in regard to its toughness and conductivity for electricity. It occurs associated with a series of very old, dark, heavy lavas, which we find around the edges of the Lake Superior basin and dipping toward it. One of the minerals of these lavas is known as chrysolite, which has been used as a gem, but although hard it is easily attacked by the weather. It generally contains small amounts of copper and nickel. It

has almost always been decomposed in these rocks, which are among the oldest sedimentaries known, so old that no trace of life has been found in them. The chrysolite has, I believe, lost its copper, which has been reduced and deposited from aqueous solution in the opener, more porous parts of the rocks, to wit: the upper parts of the lava flows, originally full of bubbles, known as amygdaloids, or sometimes in old gravel beds, known as conglomerates, or sometimes in fissures in the rocks. The two former classes of lodes run parallel with the formation, that is, in a general way, parallel to the lake shore. The last class runs frequently at right angles to the course of the formation, i. e., toward the lake.

But not every conglomerate, amygdaloid or fissure bears copper, and no one conglomerate, amygdaloid or fissure bears copper equally everywhere throughout its length. The law of distribution is very complicated, though it is safe to say that near the crossing of a fissure and an amygdaloid or conglomerate lode both are likely to be richer than elsewhere, for their intersection will make a sort of trough to guide the waters which undoubtedly have collected and deposited the copper. If, as suggested, they are laid down by percolating waters, the circulation might be more active beneath high land which is close to low land, i. e., gaps in the range.

In economic geology as in other things it is vastly easier to tell where a thing isn't than where it is, and the geologist could be of full as much service, if people would let him, in saving them from crazy schemes of exploration, boring for coal around Detroit, for instance, as in telling them where to find things. Still, we can usually be of considerable assistance in finding a copper-bearing lode. How rich it will prove remains for providence to determine; for instance, my friend and predecessor, Dr. Hubbard, now manager of the Copper Range Company, located the Baltic lode very readily on their property. I quote his account.*

"On May 10, 1898, immediately after the disappearance of snow, I began examination of the southeastern portion of the land held by the company under option from the St. Mary's Canal Mineral Land Company, where the beds of the Keweenaw copper-bearing series were known to outcrop, near what is supposed to be the line of contact between the copper-bearing rocks and the eastern sandstone. On that day I found a conglomerate in the northeast quarter of Sec. 31, T. 54, R. 34, which from its position, strike (about north 26 degrees), and dip (northwest about 71 degrees) seemed likely to be the equivalent of a belt of conglomerate about 110 feet horizontally southeasterly of the amygdaloid bed mined by the Baltic Mining Company. On the following day I found immediately under the conglomerate, a four-foot bed of amygdaloid that carries a good deal of copper.

"On May 14 a force of laborers, under charge of Capt. John Broan, began to uncover both beds, preliminary to trenching northwesterly across the series; and on the 17th, Capt. Broan, while examining with a pick the rocks toward the west, found copper in a bed about 190 feet from the conglomerate. Three trenches were dug across this bed, one of which, the so called 'discovery pit' near the present D shaft, found the 'lode' to be 37 feet wide and richly impregnated with copper.

"On May 23 trenching was begun in a valley about 1100 feet south-

* Report of company for 1900.

westerly of the discovery pit, and the lode was located there in June, and also at a point 1800 feet northeast of the discovery pit (about 100 paces southwestly of the present B shaft)."

It will be noticed that he worked from its position relative to an easily recognized bed. I may remark that the supervisors of Houghton county in assessing land values took the strike at the Baltic property and got over a mile out at the same distance.

The copper found in our Michigan mines is not usually any ore, but the pure metal, unalloyed, although a little silver is often intimately mixed. Now, just as in iron, a hundredth of a per cent of phosphorus may make the difference between Bessemer and non-Bessemer ore; so it is with copper, but more so. A ten-thousandth part of a per cent admixture of arsenic will noticeably affect its power to transmit electricity. Thus, since our mines are not only the largest of the world, but can furnish the purest copper, it commands half a cent to a cent more than the next grade electrolytic, that is a premium of 5 per cent for Lake copper over every other brand. While pure copper is typical of the lake regions, near the surface carbonates and oxides are found, and rarely in fissures the sulphides and arsenides. I mentioned that nickel and copper were generally found together in chrysolite. Recently for the first time in such a fissure (in the Mohawk mine) nickel has been found with the copper. It is not wonderful that it should be found. The queer thing is its absence hitherto.*

It was not unnatural that the same interests so largely interested in iron should become interested in copper; in fact, they were invited in—I may even say let in—in more senses than one, for I presume I am not telling tales out of school in saying that the Arcadian, Isle Royale and other so called Standard Oil properties are not the cream of the lake copper mines. But once let in they have a remarkable capacity for staying until they now control a good proportion of the United States copper output and some important Michigan mines. It has been supposed that they are about to repeat the story of the Mesabi range, but circumstances alter cases. Leaving out of the question the difficulty of getting control of a mine by any kind of stock market manipulation while its chief owners are dredging crinoids in tropic seas, or enjoying the sights of Europe, and have left no orders to sell, for this is not properly a matter of economic geology, we have to consider the following facts:

The amount of copper per ton is not generally very great—3 or 4 per cent in the Calumet & Hecla to 0.61 per cent in the Atlantic. The number and area of lodes containing copper, in percentage greater than that of the Atlantic at any rate, is probably very large, but (and this is characteristic of Michigan generally, not only in copper but also the iron and coal countries) there is a heavy mantle of drift which renders their discovery and exploitation difficult and expensive. The development of the mine and the concentration are expensive processes. The new mines that have amounted to anything have started with a fund of from $200,000 to $500,000 for exploration, and, if enough is found to warrant it, the erection of a stamp mill to crush the rock, and then by a sys-

* Transactions of Lake Superior Mining Institute, Vol. VII, pp. 62-64.

tematic process of washing extract the copper, and of a permanent plant, can easily absorb $200,000 to $500,000 more.

Thus there is no chance for a poor man or group of men to come into the copper country and unaided make their fortunes as they can in the Yukon; and, on the other hand, the various mines have strong financial backing and cannot readily be coerced. They all own their stamp mills, as I have said. Smelting the concentrates is not an elaborate process, and is performed right in the district. A number of the more powerful mines practically control their own smelters now. In fact, in the copper district not only are the copper ingots produced, but the copper wire ready for the electrician or trolley man, so that, with water transportation close at hand, it is not easy to compel men to come into a combination, and it is easy for capitalists to start another independent mine.

Thus there are geological reasons in the mode of occurrence and location of the Michigan copper mines why it will be much harder for one interest to get the grip on the copper situation than upon the iron, since there is not the same economy in it, and competition will be much easier.

SANDSTONE.

The copper-bearing series is inclined, but toward the upper part of the series the inclination becomes less and less as the younger rocks are less and less disturbed, and the formation passes without any great break into that of the Lake Superior sandstone, whose beauty in the red and white cliffs of the Pictured Rocks contrasted with green foliage of the matted cedars above and the blue waves beneath is so well known. But it also makes one of the most pleasing building stones, and the Portage redstone and Marquette brownstone are known throughout the territory tributary to the Great Lakes. In regard to the building stones, the ease of the water transportation is a most important item, yet it must be confessed that in that respect the State is far behind our neighbor state of Wisconsin and behind what we might expect. We have not a single granite quarry, though plenty of granite in the old Archean "negative pole" is not far from lake transportation.

There are a few sandstone quarries here and there in the Lower Peninsula, and yet perhaps the most interesting are not far from building stone at all. The Cleveland Stone Company is working away at the Thumb-nail* of lower Michigan, and making it into scythe and grindstones. For this purpose a combination of qualities must exist in the sandstone. It must be fine grained and even grained with a firm, tough cement, and not so hard as to glaze, to hold together the angular grains of quartz and feldspar, which are so small that under the microscope we see that their edges are sharp, and that they have been floated along in the water rather than rolled into place and rounded.

Down in the southeast corner of the State there is another sandstone, white as the driven snow and almost absolutely pure SiO_2, which is an admirable material for glass manufacture, is also used in sanding paint and matchboxes, but not for sugar.†

* Vol. VII, Part I.
† Vol. VII, Part II.

LIMESTONE.

Just as building stone is but one of the uses of sandstone, so it is but the least of the uses of limestone. Few people realize the variety of uses of the limestone, with which this State is well provided. For building stone, for macadam, for quicklime, for Portland cement, in making bromine, and in making from our own salt deposits the soda-ash which is the basis of our baking powders, washing powders, seidlitz powders, to reduce our iron and copper ores, to line steel converters, and to clarify beet sugar syrup, limestone is used.

Each one of these uses makes different demands. For macadam it must be tough; for Portland cement it must be tender, and either argillaceous itself or near clay or shale as well as fuel; for converter linings it should be magnesian, but most of the chemical industries require it as pure as possible, protesting more or less if over a fiftieth part of impurities occur, and each industry has its own pet aversion among impurities.

SALT.

This list of industries in which limestone is an important raw material suggests an almost endless vista for consideration. Without touching on all, we cannot omit alkali manufacture. You know that salt manufacture is one of the great industries, and one of the necessities of life, upon which oppressive governments fasten their taxes, for they know that people must pay. Eighty million barrels of salt has Michigan produced, and is still producing at the rate of five million per year,* over a fourth of the product of the United States, and the ease of obtaining it and making it ready for the market is so great that no monopoly can exist that will raise the average price for more than a year over a tenth of a cent a pound. Think what it means to the packers of Chicago to have this storehouse of salt at their very doors! The salt is obtained either from the evaporation of strong brines contained in four or five different sandstones, or from beds of rock salt many feet thick. The waters of the St. Clair and Detroit rivers are pumped down upon them to dissolve them, for there is no mining as yet.

While we all realize the importance of salt, few realize the fact that soda is largely made from it, nor how important soda is in the framework of modern society. The soda-ash business is one of the foundation stones of chemical industries. Thus I have prophesied that Michigan will be the home of the chemical industries for the Mississippi valley.

These same brines and salt beds which yield the salt and soda are not only fountains for the "healing of the nations," as at Mt. Clemens and St. Clair, but will yield potash and bromine, the manufacture of which latter source of soothing for Americanitis and base of best photograph paper is controlled by Michigan.

By-products of the soda-ash business are calcium chloride and bleaching powder, and, though this latter has a number of uses in refrigerating and in making artificial stone, it piled up faster than they could dispose

* 96,993,584 through 1901, 5,580,101 that year, *not* counting that which is used in making soda.

of it, so the Michigan Alkali Co. at Wyandotte have taken to mixing it with the mud of Detroit river and making Portland cement of it. At Alpena Portland cement is made of limestone and shale. But, as you doubtless know, most of the factories of the State are making it out of the calcareous mud at the bottom of our lakes and clay.

Our limestone supplies are beginning to be appreciated, but in clays and shales as in building stones we are behind out neighbors on the south, though we have glazing clays, paving brick clays, clays suitable for Portland cement, and others which are or will be the source of livelihood to many. Most of our surface clays, however, have too much lime for many uses.

GOLD, PEARLS, DIAMONDS, ETC.

It will be noticed that most of the things I have mentioned are what might be called common things and cheap things, and I might have gone on and discussed the adaptability of our soils for some of the crops for which Michigan is famous, such as sugar beets, peppermint, celery and fruit. But I have said nothing about gold, though a production of $632,444 in the last 13 years shows that it will become a settled industry, have barely mentioned silver, which is merely a by-product of copper, have said nothing about pearls or diamonds, though once in a while a Unio yields a pearl, and an occasional diamond found in the gravel of Michigan or Wisconsin may perhaps have been derived from some of our Upper Peninsula serpentines. I have not even mentioned chlorastrolite, peculiar to the beaches of Isle Royale, for I have not tried to give an illustrated catalogue of products,—time, my breath, and your patience would fail,—but rather to select for description certain raw materials whose occurrence, exploitation, and use illustrate certain principles applicable not merely in Michigan but everywhere, which may be summed up thus:

CONCLUSION.

The ultimate raw materials are a part of the earth's crust. Their value depends on the relative ease with which they may be turned into the finished product, which in turn depends on their accessibility to other raw material and to market.

The modern tendency to consolidation takes place:

First, by the union of similar and parallel plants into enormous establishments. This results in the consumption of large amounts of raw material by individual owners, and this in turn justifies a scrutiny ever growing more severe to see that the raw material is the best both in quality and location. In spite of this, the tendency has ever been to use ore deposits, lower in grade, but whose quantity and circumstances enable them to be handled cheaply in large quantities at a profit.

Second, consolidation takes place by union of successive industrial links in the line from the ultimate raw material to the consumer. This tends to eliminate competition by making it impossible to compete except all along the line. When the sources of any necessary raw material are controlled, competition in the whole industry becomes impossible.

Finally, the raw materials of greatest value to the State and civiliza-

tion are not the rare and costly things, but those things common as dirt, whose value depends largely upon their location mutually and relatively to their market, which are needful to sustain a varied and hence vigorous and intelligent industry.

Of the various subjects mentioned above, the following have received especial study this year:

A report on coal* is entirely in the hands of the printers and should certainly be issued before this annual report. It is based on the report printed in the first volume of the Michigan Miner, but a very slight inspection will show a large amount of new work and new material, especially as to the chemical quality of the different seams.

A report on marl and the Portland cement industry will form Part III of Volume VIII. It contains Mr. David J. Hale's studies on the use of marl or bog-lime, Mr. C. A. Davis' studies on the origin of marl, and especially the important contribution that vegetation has made thereto, and the studies of Mr. B. Walker upon the species of shells that are found therein, and also a review of some of the economically important bog-lime deposits. It is hardly possible to make this exhaustive, for there are 5000 lakes and over in the State, and I should think one-third have more or less of these bog-lime deposits, which also occur in many marshes which are not connected at present with lakes.

It will appear from this report how abundant marl or bog-lime is, though the full working thickness of the deposits is rarely as pure calcium carbonate as published analyses would indicate, how it usually lies in a shelf around the lake, and under the bordering marsh, or has filled in the lake completely, and how largely it is deposited by the lake weed of the genus Chara, and is of recent origin and now being deposited. Mr. Walker also finds but little sign of change of life in the marl. The following letter summarizes some of his results:

Detroit, Michigan, Nov. 25, 1901.

A. C. Lane, Esq., Lansing, Michigan:

My Dear Sir.—I enclose my report on the mollusks found in the seventeen lots of marl material received from yourself and Prof. Davis during the last two years. I have not included the recent species of which several lots were received from Prof. Davis as this determination was not pertinent to the marl fauna particularly. I can send you a list of them if you desire. There is however nothing of special interest in them and the list of Saginaw valley shells which you made use of in your former report will include them all.

Taken as a whole the fauna of the marl deposits does not differ from the present fauna of that portion of the State from which they come. Nor have I found in the specimens from any particular locality any special peculiarities which would indicate peculiar local conditions of environment. Individual variations occur, more or less frequently, but no more than is often found in similar collections of recent species. The inference is therefore that the marl fauna lived under substantially the same environmental conditions as the present fauna does, or at least not sufficiently different to produce any special or characteristic variations.

The one species peculiar to the marl deposits of this State is *Pisidium contortum* Prime. It was originally described from the post-pleiocene formation at Pittsfield, Mass. It occurs abundantly in the marl deposits both in Michigan and Maine. It has recently been found living in one locality in the latter state and it is quite possible that it may yet be found alive in this State. But so far as our present knowledge extends it is extinct in Michigan. Why this one species out of the fifteen, included in our list, to say nothing of the other genera represented in the marl, should have failed to survive, while all the others are still abundantly represented in our present fauna is very curious. I have been entirely unable to imagine any adequate explanation.

* Vol. VIII, Part II.

The characteristic feature of the marl fauna is the great relative abundance of certain of the smaller species. This is especially noticeable in *Planorbis parvus* Say, *Valvata tricarinata* Say and *Amnicola limosa* Say and *lustrica* Pill. The larger *Planorbis bicarinatus* Say and *campanulatus* Say occur in nearly every lot of material, but the number of individuals is comparatively small. *Pisidium* both in the number of species and individuals is also a characteristic feature of the marl as it is indeed of our present fauna. There is probably no district in the United States in which this genus abounds to a greater extent, both in species and individuals than in the inland waters of this State.

The terrestrial species represented in the marl are few both in number and individuals. This is what would naturally be expected as those that do occur are the occasional examples that have been washed into the water from the adjacent land. Such as have been found present no peculiarities as compared with recent specimens from the same region.

The almost complete absence of the *Unionidæ* from the collections is also noticeable.

The peculiar variations noted in *Valvata tricarinata* Say from Cement City are of considerable interest. A similar tendency to unusual variation, although in another direction, has been noticed in the same species from a post-glacial deposit near Niles in this State (Nautilus XI, p. 121). In both instances however the variation was not common to the whole colony but was limited to a very few individuals. It cannot therefore be attributed to any peculiar conditions in the environment, for in that case it would undoubtedly be more general in effect.

Please do not forget to give Dr. V. Sterki the credit for identifying the Pupidae and Pisidia.

Yours very truly,

(Signed.) BRYANT WALKER.

LIMESTONES.

LIMESTONES.

Upon the uses of limestone we have already touched. A good deal of material as to their physical character will be found in previous reports, especially Part I of volume VII and Part III of volume I, by Dr. Carl Rominger. But it may be well to run over them briefly, particularly referring to their chemical character, which is of especial importance in their new uses, in sugar, soda and bromine manufacture, since these reports are out of print and scarce.

I may say to begin with, that in using the term "limestone" for the heading of this article, I include not merely carbonate of lime, but limestone as we find it, a mixture mainly of carbonates either of lime or magnesia, and more or less iron, strontium, etc., with clay or sand, and the uses for which limestone serves as raw material vary greatly according to its composition. For instance, there is a very great demand for anything like pure carbonate of lime, and as soon as it gets near 98 per cent it can be used in the manufacture of calcium acetate in connection with charcoal kilns, the clarification of beet sugar syrup, and generation of carbon dioxide for soda water and for making soda carbonate out of soda chloride, as well as for burning lime or making Portland cement by admixture with clay.

In the Midland process for the manufacture of bromine it is also used. As I understand it, chlorine water decomposes the bromine which is blown out by an air current and collected by quicklime.

The demand rapidly drops as the per cent of $Ca\,CO_3$ falls, and by the time it has sunk only 4 or 8 per cent, to 94 per cent of calcium carbonate, the chemical industries have ceased to demand it. It still may be burned into a hot lime which will stand much sand and it will serve very well for blast-furnace flux. Generally as the per cent of magnesia increases, the lime becomes milder and slower setting and quality poorer, until by and by, at about 20 per cent MgO, it ceases to slake, becomes hydraulic and becomes a dolomitic limestone which, if properly massive, makes a good building stone, but is not good for much else. Then as the per cent of magnesia increases it becomes a refractory material suitable for basic furnace linings. Finally, pure magnesia carbonate comes into demand once again by chemical manufacturers to produce carbonic acid gas* and the salts of magnesia. This is but a rough outline sketch of the uses of one series of calcium and magnesium compounds, and the relative percentages of the various impurities which are tolerable vary according to the special use. I am told that not over 3 per cent of MgO is allowable in the manufacture of cement, whereas there is much greater latitude in percentages of alumina, silica and iron.

* The presence of lime when the stone is dissolved in sulphuric acid produces plaster of Paris and clogs the working.

For use in beet sugar the limestone should make a lime which is not lumpy, but slakes readily to a milk. The magnesium saccharate is more soluble and makes more ash in the sugar, and hence should be avoided.

It will be of interest to take up the limestones of Michigan geologically and geographically, pointing out where they are conveniently accessible, what their composition is likely to be, and what uses have been or may be made of them. Their general distribution is indicated on the map given herewith. Plate IX.

Beginning with the oldest rocks, we find down in the Archean,* associated with the iron-bearing or Huronian rocks, beds of dolomite which have been so hardened and re-crystallized that we may safely call them marble, a term which has been applied to many other of our limestones with less justification. The amount of the various carbonates contained probably varies, but they are generally truly dolomitic. One formation is known by the United States Geological Survey, around Marquette, as the Kona dolomite. Farther south they call it the Randville and Antoine dolomite. These beds have been used at times as a flux in iron smelting and might be used more if the reduction of iron ore were carried on very much in the Upper Peninsula. But they are extremely hard and their silicious character makes them rather unsuitable for use with ores which are already too silicious. Analysis No. 1, given by Rominger, is from one of them. Other analyses made for H. L. Smyth show a considerable though variable percentage of carbonate of magnesia, from 16 per cent to 42 per cent and are given just below.

Sometimes they present a handsome porphyroid appearance. I have seen large, deep red crystals sprinkled in a pink ground, which made a very handsome and attractive ornamental stone. I suspect, however, that there would be a good deal of jointing and waste. Crystals of tremolite also occur. These dolomites are not close to the water and the rigor of the climate would have to be considered in planning to quarry them.

Analyses of Randville dolomite by G. B. Richardson:

	I.	II.	III.
Insoluble in HCl	2.0	9.7	29.1
Fe_2O_3	1.2	2.1	2.2
$CaCO_3$	53.2	48.9	39.3
$MgCO_3$	42.3	38.0	27.7
Total	98.7	98.7	98.3

Analyses of dolomites from Michigamme mountain area by R. J. Forsyth:

	I.	II.	III.
Residue insol. in HCl	14.25	9.34	.....
$Al_2(Fe_2)O_3$	11.15	12.57	5.38
$CaCO_3$	47.18	45.98	36.60
$MgCO_3$	18.48	19.22	16.38

We cite from Bulletin 168, a number of analyses and of them "A" of the series made in the United States Geological Survey laboratory may belong to the same formation.

* I use Archean, as used by Dana its sponsor, to include all Precambrain rocks.

Analyses of Archean dolomites and kindred rocks, from the United States Geological Survey laboratory:

	A.	C.	E.	F.	G.	H.	I.	P.
SiO_2	3.07	7.05	3.16	28.86	46.47	46.01	36.73	42.37
Al_2O_3	.....	.48	.08	1.29	.70	.83	.38	.....
Fe_2O_3	.09	1.33	.93	1.01	.86	1.35	.98	1.09
FeO	.86	Undet	15.18	37.37	28.57	26.07	34.81	31.41
MnO	.15	.19	1.15	.97	.40	2.09	.52	.....
CaO	29.72	50.08	26.65	.74	.49	.63	.48	.50
MgO	19.95	.57	11.01	3.64	2.30	2.86	2.74	2.48
H_2O at 105°	.30	.25	.54	.68	.60	1.71	.12	.....
H_2O ignition							1.40	.....
P_2O_5	.....	.27	.06	Trace	Trace	.07	.01	.....
CO_2	45.31	39.68	41.10	25.21	19 24	17.72	22.44	21.80
SO_3	.....	.21	.....	.....	.....	.15	.16	.....
Cl	Trace	.....	Trace	.....	?	.....	.....	.....
FeS_2	.....	.....	.34	.....	.....	.....	.....	.....
TiO_2	.....	.....	.....	.20	.10	.12	.19	.....

A. Dolomite. Near Sunday lake, Gogebic district, Michigan. Analysis by W. F. Hillebrand, record No. 767.

C. Limestone. Bed of Slate creek, Huron Bay slate quarries, Michigan. Analysis by T.M. Chatard, record No. 894. From laboratory records.

E. Iron carbonate, from S. E. ¼ Sec. 20, T. 47 N., R. 43 W., Michigan.

F. Iron carbonate. South side of Sunday lake, Michigan.

G. Iron carbonate. Palms mine, Gogebic district, Michigan. Analyses E, F, G by W. T. Hillebrand, records Nos. 769, 770, 771.

H. Iron carbonate. Miner and Wells option, Sec. 13, T. 47 N., R. 46 W., Michigan. Analysis by T. M. Chatard, record No. 893.

I. Iron carbonate. N. W. ¼ Sec. 18, T. 47 N., R. 45 W., Michigan. Analysis by Chatard, No. 895.

P. Ferrodolomite. Marquette district, Michigan. Analysis by George Steiger, record No. 1473.

	Q.	R.	S.
SiO_2	26.97	26.67	.30
Al_2O_3	1.30	.12	1.18
Fe_2O_3	2.31	.16	2.15
FeO	39.77	.....	39.77
MnO	.29	.....	.29
CaO	.66	.....	.66
MgO	1.94	.10	1.84
Alkalies	.09	.....	.09
H_2O at 100°	.10	.....	.....
H_2O above 100°	.51	.....	.....
P_2O_5	.03	.....	.03
CO_2	26.20	.....	26.20

Q. Ferrodolomite. Marquette district, Michigan.

R. Portions of Q, insoluble by hydrochloric acid.

S. Soluble portion of Q. Analyses of Q, R, S by George Steigner, record No. 1442.

Associated with the iron ores in certain cases are ferrodolomites E, F, G, H, I and P, which Irving imagined to have been an early form of the iron ore.

The Archean marbles are exploited by the North Michigan Marble Company in Dickinson county, on Sec. 26, T. 48 N., R. 28 W. The Commissioner of Mineral Statistics reports as follows: "Some of it is pure white, some variegated, shading from white to pink, green, gray and purple, making beautiful slabs for wainscoting and interior work. It is somewhat granitic in nature, sufficiently so that the tests given foreign

and New England marbles will not tarnish the highest polish. It is susceptible of a polish almost equal to onyx. There is pressing demand for the stone beyond anything that they can supply, even the chips and small spalls being disposed of. One concern in Chicago has used several carloads of small chips. The price received is from $3 to $4 per ton for the rough rock that is produced in opening the quarry, and from $2.50 to $5 per cubic foot for sound, square-channeled rock."

Before leaving the subject of Archean marble, a word should be said garding the verde antique marble. This is really a decomposed product of peridotite and is strictly to be classed under the serpentines, although it frequently, as Rominger's analysis (2) shows, becomes a carbonate rock. The beauty of the serpentine and verde antique for interior finish needs no statement, and the Michigan outcrops prove to be quite as good as any. Mr. Julian N. Case of Ishpeming took the trouble to have a certain amount worked up, and I have heard it very highly praised by such architects as Mr. Patton of Patton & Fisher. The death of Mr. Case interfered with its exploitations and I do not know that it has yet been commercially developed. Serpentine occurs in a number of places mentioned in the 1892 report of the Michigan Geological Survey (p. 134). The principal area lies north of Marquette and Ishpeming, being exposed from Presque Isle to north of Ishpeming, beginning in the eastern port of Sec. 27, T. 48, R. 27, and extending in a southwesterly direction to Sec. 2, T. 47, R. 28. It is also to be seen in T. 44 N., R. 32 W., and in Secs. 22 and 28, T. 42 N., R. 31 W. An analysis of such a dolomite serpentine product is given by Rominger (No. 2).

The Keweenawan series contains some large veins of calcite, and associated with the copper are sometimes crystals of calcite as pure and clear as Iceland spar. I do not know of any vein, however, which could be an economic producer of lime in a large way.

It is not until we begin to get above the Potsdam sandstone toward the Trenton that we begin to get calcareous beds again in a large way. The Calciferous strata may be taken as a group of beds which form a transition from the sandstone to the almost purely calcareous Trenton. Analyses seem to indicate† not over 54 per cent carbonate of lime and not less than 32 per cent nor more than 42 per cent of carbonate of magnesia. There is generally considerable sand. Analyses by Rominger (3 to 14) suggest that basic furnace linings might be obtained from the formation, and its outcrops along St. Mary's river would be readily accessible. It appears also to be a durable building stone and in some cases has a tendency to oölitic structure.

It is well exposed and could be easily quarried near Chatham, the Upper Peninsula agricultural experiment station. An analysis gave the chemist:*

Insoluble sand (SiO_2)	35
$(FeAl_2)O_3$	5
$CaCO_3$	32
$MgCO_3$	22
Difference (water and organic)	6
	100.00

The ratio of lime to magnesia is similar to that in Rominger's analyses.

* Bulletin 186, Dec., 1900.
† See page 70, part I, Vol. 3, Michigan Geological Survey Reports.

I see no reason why this would not make converter linings.

The Trenton formation, generally speaking, is less silicious, and while in a general way there is a great deal of dolomite in it, not infrequently we find streaks which are a high grade of limestone like Rominger's analysis (20) from the Escanaba river. I have heard of even purer material. The Trenton forms the northwest shore of Green bay, where it could easily be obtained, as well as on St. Mary's river.

The next group of beds, the Cincinnati and Hudson river group, are usually spoken of as shales or shaly limestone. As a matter of fact, however, the only part where they are shown in our State, where they run from the point which splits the upper end of Green bay, they are quite calcareous, as shown by Rominger's analysis 24 as well as Keonig's tests below.

For lime burning or for building, however, the beds are too argillaceous. There is a great deal of variation from bed to bed, and even along the beds. The argillaceous character of the beds suggests that they might be suitable for the manufacture of hydraulic cement. But the following series of tests shown me by Prof. G. A. Koenig of the Michigan College of Mines makes it probable that they are too irregular in composition for that purpose:

ANALYSES, BLUFF OPPOSITE GLADSTONE, MICH., OCTOBER 7, 1899.

No. of sample.	Per cent. $CaCO_3$.	Thickness of beds in inches.
1	42.4	
2	50.4	
3	63.3	30
4	52.8	
5	48.0	19
6	50.8	
7a	57.3	4
7b	46.0	
8a	49.6	6
8b	49.6	
8c	51.6	5 spotted.
9	66.4	5 spotted.
10	42.4	3
11	45.2	6
12a	50.4	10
12b	43.2	
13	44.0	6
14	54.0	8
15a	42.0	13
15b	44.0	
16a	42.0	
16b	43.6	30
16c	40.0	
16d	40.0	
17	34.00	7
18	36	30
18	32	

Samples with the same number but a different letter are from the same level or horizon, but taken at different points. The residue is very largely insoluble, argillaceous.

The Niagara limestones are a very well defined belt and in their best estate, shown in Rominger's analysis (No. 30), fairly free from anything but carbonates. They are characteristically very light colored, and the drillers have often referred to them as snow-white marble. We know from the records that they lie beneath the whole State, but their outcrop

is confined to the well marked ridge which separates Green bay from the rest of Lake Michigan and is frequently exposed clear to Drummond's Island. Some idea of their chemical character is given by Rominger's analyses Nos. 26 to 36, from which it will appear that usually they are dolomite, though analyses Nos. 30 and 31 indicate a limestone very low in magnesia, and he says that the white lenticular-like masses, between the beds of the Burnt Bluff section, are almost pure carbonate of lime. Other reports have come to me which show that there is doubtless quite high grade limestone in the series.

On Sec. 16, T. 44 N., R. 7 E., on land belonging to Chase S. Osborn, is an interesting group of caves in this limestone, which here appears to be exceptionally free from magnesia. Perhaps this has something to do with the origin of the caves. I visited them August 3, 1901. As they are approached from Lewis Station to the south there is little or no relief, occasional sandy rises in the midst of swamps, until not far from the southeast corner of the section the trail passes between some small sinks, which are the entrance to several hundred feet of cave, low and flat, in general not over two or three feet high, but with a channel six to eight feet deep cut in beautiful meanders which slightly increase the size of loop as they cut down, and are barely wide enough for a man to walk in them.

The stream finally falls by a cascade into a larger and picturesque sink hole about 30 feet deep, in which no outlet could be found. It was probably concealed by broken rock.

About one-third mile north and one-fourth mile west the trail passes over a couple of sinks, the one to the west being much larger and showing under the road a fine portal to a larger cave, which was, however, at the time of our visit much fuller of water, though from what I learned I judged that it may have been a temporary choking up.

Continuing north the country soon drops off more rapidly.

This limestone is said to be very pure and suitable for the manufacture of calcium carbide. There must be a considerable area, with little stripping and easily drained.

The Niagara limestone is also extensively exposed and has been burned for lime along the D., S. S. & A. railroad, not far off, from about one-half mile north of Ozark at frequent intervals on hills rising up to 40 feet above the track, which passes through a limestone a little more than a mile southeast of Ozark. It is white irregular crystalline, with corals such as Favosites, Cystiphyllum and Monticulipora.

Then again at Palms, and Jere. Taylor's, one-half mile east, were quarries. The kilns supplied the Newberry charcoal iron furnaces, and stopped when they stopped, but the lime is highly spoken of locally.

The White Marble Lime Company of Manistique, Mich., is also making lime from the Niagara, and furnishes the following analysis:

	Unslacked lime.	Limestone.
Silica	1.80	1.50
Iron and aluminum	.90	.....
Lime	52.40	52.77
Magnesia	44.65	45.75
Balance	2.05	.....
	100.00	100.02

The freedom from insoluble matter is noteworthy. There are, however, cherty and silicious layers in the Niagara.

The amount of iron and alumina is in general the lowest of any formation. The most constant impurity, probably, is a certain per cent of pure quartz sand, so pure that by itself it would make glass sand. The Niagara could be easily quarried at many points and readily handled by water. A curious bed of this limestone and all those below it is caught and held in a very sharp fold a few miles from the head of Keweenaw bay on Secs. 13, 14, 23, 24, T. 51 N., R. 35 W., and a hill near by. The Niagara is characterized by many well defined fossils, of which the "chain coral" is as familiar and easy to recognize as any.

Above the beds of the Niagara come the beds of the Salina and Lower Helderberg series or, as I have called them all, the Monroe beds. At several points of this series dolomites and dolomitic marls occur. Around St. Ignace the series appears, and on Mackinac Island also, but it has mainly been developed in the extreme southeast part of the State, where it has been carefully studied by Prof. W. H. Sherzer in the Monroe county report.*

This region lies so close to the large cities of Detroit and Buffalo that it has been very extensively developed for building stone and for road matter, and to some extent for lime. The rock is in general silicious dolomite and seems to have more or less sand, and is sometimes marketed as sandstone, and indeed passes into it by degrees, as is shown by the following analyses from the Woolmith quarry, the third of which is distinctively sandstone. Frequently large blocks have been quarried.

Woolmith quarry analyses cited by Sherzer:

	I 4 ft. down.	II 18 ft. down.	III 24 ft. down.
Silica	6.19	3.05	97.76
Iron oxide and alumina	.45	.31	.55
Magnesia carbonate	43.53	44.59	1.43
Calcium carbonate	50.12	52.72	1.14
Difference	.29	.67	.88
	100.00	100 00	100.00

Other analyses of dolomite along the line of the Pere Marquette are, according to General Manager S. T. Crapo:

	I	II
Silica and insoluble	2.33	5.92
Iron and alumina	.48	.52
Carbonate of lime	55.03	53.16
Carbonate of magnesia	42.17	40.36
	100 00	100.00

An analysis by J. D. Pennock of dolomite from a Raisinville quarry, claim 516, is as follows:

Silica	3.45
Iron oxide and alumina	.20
Calcium carbonate	51.69
Calcium sulphate	.43
Magnesium carbonate	45.01
Difference	.78
	100.00

* Vol. VII, Part I. Analyses cited are on pp. 82, 83, 95.

The Monroe Stone Company have a quarry about two miles north of the city of Monroe which has given K. J. Sundstrom the following results:

	2 ft. down.	7 ft. down.	10 ft. down.
Silica	.70	.98	.58
Iron oxide and alumina	.01	.22	.31
Calcium carbonate	54.54	54.47	54.94
Magnesium carbonate	42.75	43.59	42.84
Difference	.....	.....	.....
	100.00	100.00	100.00

An interesting feature of the dolomites of Monroe county is the presence of considerable quantities of strontium, both the carbonate strontianite and the sulphate celestite. These are also found on the islands of Lake Erie. Aside from their value as a source for red fire, they could replace lime to great advantage in the manufacture of beet sugar. No analyses for strontium are known to me, so that I have assisted Mr. W. K. Wonders of the Agricultural College in collecting material for a thesis on this subject.

The places in Monroe county where the dolomites of the Helderberg series are mainly worked are around Monroe (near which are a number of quarries), Brest, La Salle, near Samaria on the Ann Arbor line, and around and near Whiteford. The only one of these places where the industry is carried on on a large scale is Monroe, where there are lime kilns and rock crushers. The Monroe rock is a dolomite which shows by analysis for H. H. Dow by A. W. Smith:

	I.
Calcium carbonate	54.47
Insoluble	1.12
Iron and alumina	.16
Magnesium carbonate	43.47

It yields a limestone which slakes slowly, does not develop much heat, and cannot take much sand. From Monroe county in 1899 some 55,706 tons were shipped. The usefulness of some beds is greatly impaired by a brecciated character. They are real limestone conglomerates. The brecciated and conglomerate character is even more conspicuous in the northern part of the State around Mackinac Island, and renders much of the rock useless for any purpose. Rominger's analyses 37 to 41 show that the rock here also is a typical dolomite.

Next above these beds come beds which contain more calcium carbonate; in fact I have drawn the line between the Dundee and Monroe, so as to make it coincide with the division between the limestones of the upper Helderberg or Corniferous and the dolomite of the lower Helderberg or Waterlime (Manlius). This difference in chemical character appears quite uniform throughout the State, as is shown by very numerous qualitative tests on drill borings as well as the quantitative analyses given. The purer Dundee limestones are one of the important horizons of the State, which I think will be even more developed in the future. The most extensive quarry is that of the Sibley Quarry Company of Detroit river, in the south part of Wayne county.

All through this region we find this general distinction between the Dundee or Corniferous, running high in calcium carbonate, and lower Helderberg or Monroe beds, with low per cent. I may state that at

Monroe there is about 50 per cent of calcium carbonate, at Gibraltar and Grosse Isle 62 per cent, at Newport and Brest somewhat higher, about 80 to 84 per cent, and at Amherstburg 92 per cent, while the Sibley quarry probably runs best of all with 94 to 98 per cent of calcium carbonate. The 9-foot blue bed, it is said, can be so picked as to give 98 per cent, guaranteed at each shipment. Below are given some of the analyses from some of the beds of the Sibley Quarry Company. It will be noticed that not all are high in calcium carbonates, but are useful for macadam, lime, building stone and other purposes, while the beds high in calcium carbonate are reserved for chemical purposes.

The region along the Detroit river is very well suited for such industries, for it is on the water, has ample railroad facilities, has the high grade limestone of the Sibley quarry, and by boring 800 or more feet down an indefinite supply of rock salt can be obtained. Some of the beds are of great thickness as is shown by the record of the well at Royal Oak, given in Vol. V of our reports, and records elsewhere printed in these reports. The only well of which we have an accurate record, which has passed clear through the salt, is that at Wyandotte, which is reported in the same volume and reached Trenton rock at 2610 feet. Suffice it to say that from 800 to 1500 feet down there is a very large supply of rock salt. The use of carbonic oxide for the making of soda is so extensive that the calcium chloride becomes a product which is manufactured faster than it can be used. The Solvay Process people, who are manufacturing soda at the old exposition grounds, are using the chloride of calcium to make land and redeem a marsh, known as Zug Island, good property. Calcium chloride is used as the basis of a number of artificial stones. It is also employed in refrigeration, as calcium chloride can be circulated through pipes at a very low temperature with no danger of freezing. But this is not the only use for the Sibley limestone. Michigan has within two or three years leaped into prominence as a producer of beet sugar. It has just the right climate, many of the hard lake-clay soils with a light coating of sand on top, have just the right character for the growth of sugar beets. And there is a good German population who are not afraid to work and make good growers of the beets. Consequently we have a number of factories established at Kalamazoo, Rochester, Alma, Lansing and elsewhere, which largely depend upon the Sibley quarry for their supply of calcium carbonate.

The soda ash men, who originally planned to manufacture soda ash here, have probably got a better thing in their limestone quarry than in the manufacture of soda. The drillings here show clearly and sharply by the sudden rises in magnesia the line between the Dundee and Monroe (Corniferous and Waterlime), and the very best beds run over 98 per cent of lime. A section of the quarry will be as follows:

A. 6-foot bed of limestone, thin layered, very fossiliferous and a high grade limestone.

B. 7-foot bed, 2 to 11 inches thick, more coarsely crystalline, somewhat pyritic, not so conspicuously fossiliferous.

C. 2 feet limestone with much cystiphyllum.

D. 5 feet limestone with a deposit of black carbonaceous material full of crinoids and bryozoa.

E. 6 feet limestone, almost solid mass of crinoid joints, bryozoa, corals, and brachiopods. Between D and E there is also a carbonaceous deposit.

F. 14-inch bed, mainly of chert, which contains only 3 per cent or so of $CaCO_3$.

G. 6 feet limestone, light gray and full of crinoids, etc.

H. 2-foot bed of chert about 30 inches thick, very friable, of a hard, ringing, impure matrix, when sent to the crushers.

I. 9 feet pure limestone, supposed to be the best bed of the quarry and frequently runs over 98 per cent of calcium carbonate.

J. 6-foot magnesian bed. It is magnesian only, however, in comparison with I, for it is really a fairly pure limestone but not so pure as I.

K. 8-foot bed of limestone full of the usual fossils. A thin bed as exposed and good for lime or building purposes. Prospect holes sunk from bed I show limestone for 83 feet and for 40 feet down calcium carbonate from 81 to 93 per cent, magnesia from 2½ to 16 per cent, and silica from 0.73 to 7.24 per cent.

Below this we find a sudden drop in calcium carbonate, which runs from 54.27 to 70.54, while the magnesia carbonate runs from 23.49 to 43 per cent.

Analyses of limestone from the Sibley Quarry Company, K. J. Sundstrom, chemist:

	$Ca\,CO_3$	MgC_3.	$Fe_2\,O_3$-$Al_2\,O_3$.	$Si\,O_2$.	Diff.	Rem.
A 6 ft. top bed	91.75	2.52	0.34	1.82	1.57	.....
B 6 ft. gray and blue bed	92.00	4.62	0.28	1.92	1.18	.....
C 2 ft. blue bed	94.50	3.36	Trace	1.04	1.10	.....
D 5 ft. blue bed	93.50	4.20	"	1.08	1.22	.....
E, F 6 ft. blue bed upper	87.00	9.45	0.58	2.24	0.73	.....
G 6 ft. blue bed lower	85.75	10.29	0.20	2.56	1.20	.....
H 2 ft. flinty bed and all flint beds	53.50	12.18	3.45	30.87	0.87	.....
I 9 ft. blue bed	93.50	2.73	1.12	0.64	2.01	.....
J Magnesia bed	74.00	20.58	0.74	3.74	0.94	.....
K 8 ft. blue and gray bed	87.00	9.66	0.16	1.62	1.56	.....
10 ft. blue bed	94.00	2.10	1.86	0.91	1.13	.....
Flinty layer top of 8 ft. bed and top of 10 ft. bed	43.50	9.66	2.03	43.76	1.05	.....
6 ft. lower bed	92.60	5.40	.....	.....	0.72	.....

Analysis of different beds in the Sibley quarry:

Kiln bed: 6 ft. blue bed.

$CaCO_3$	94.404
$MgCO_3$	2.180
Al_2O_3	Traces.
SiO_2	2.960
Diff.	0.456
	100.000

Five foot upper bed, dried.

$CaCO_3$	91.15
$MgCO_3$	4.87
Al_2O_3	.....
Fe_2O_3	2.90
SiO_2	1.08
	100.000

	$CaCO_3$.	$MgCO_3$	Al_2O_3.	SiO_2.	Diff.
Bed No. 2 W. bank	89.7	4.8	2.85	1.06	1.59
Bed No. 1 W. bank	86.79	6.8	2.50	2.00	1.91
Lower 6 ft. bed west side	80.36	14.05	2.71	2.88	.....
" " " south side	81.95	7.20	6.60	2.29	1.96
Middle bed building stone	83.87	6.29	6.82	3.02	Dried
Very top bed	78.58	14.26	4.75	2.41	"

Very much the same limestone beds as those of the Sibley quarry are exposed on Macon river and have been quite fully described by Rominger (analyses 46 to 47) and Sherzer, who quotes, p. 76, the following analyses, the first four by G. A. Kirschmeier, the two latter by K. J. Sundstrom:

	Bed A.	Bed B.	Bed C.	Bed D.
Calcium carbonate	90.80%	86.80%	77.60%	95.00%
Magnesium carbonate	6.87	11.60	17.41	3.86
Silica	.48	1.10	2.78	.81
Iron	.16	.12	.56	.41
Organic matter	1.69	.....	1.63	.....
Difference	.00	.38	.02	.08

Calcium carbonate	98.10%	86.96%
Magnesium carbonate	.63	10.08
Silica	.70	1.86
Iron oxide and alumina	.....	.62
Sulphur	.055	.123
Difference	.515	.....

The drainage and transportation facilities of these quarries are not as good as at the Sibley quarry.

When we pass to the northern part of the State we find indications of the same contrast of limestone and dolomite between the Dundee and Monroe (Corniferous and Waterlime). The Dundee or Corniferous extends from the Straits of Mackinac and the islands west of Presque Isle

north of Grand lake in Alpena county. But in this northern part a group of rocks not conspicuous in Wayne and Monroe counties are important—the Traverse group, full of fossils, of considerable economic value, corresponding more or less closely to the Hamilton and Marcellus (Erian) of New York. Mr. A. W. Grabau has recently begun to work them up in some detail for us and his preliminary report follows.

We leave to him these limestones, and above there are no more limestones of commercial importance for quite a long distance. There are, to be sure, nodules of lime in the Devonian black shales* which are quite pure carbonates of lime, with some organic matter, and in the shales of the Carboniferous likewise, we find nodules and bands of carbonate that are in most cases mainly carbonates of iron. They have been used from time to time for iron manufacture, but it is very doubtful if there is anything commercial. When we get up higher to the beds in which the famous Grand Rapids gypsum beds occur, at the horizon of the Burlington and Keokuk of the Mississippi valley, we find limestone again. This time it appears very much like the cement rock of Milwaukee and, although it has never been developed for this purpose, a fair quality of rock cement could doubtless be made from it. Portland cement will probably replace rock cement in this neighborhood, however. The most promising place to investigate this limestone would be in the neighborhood of the gypsum quarries of Grand Rapids and along Saginaw bay, in Iosco and Arenac counties,† in Huron county near Soule and Oak Point, and also in the valley of the Cass near Cass City.

Above the Michigan series we come to a much more important limestone horizon, which has been extensively quarried at Grand Rapids and is now quarried at Bellevue, Bayport and Arenac county. It corresponds in part to the St. Louis limestone and the Maxville limestone of Ohio, and contains some layers which are nearly pure limestone. There is some dolomite and other layers are more or less argillaceous, and it tends, however, to be rather silicious and often pyritic. Some of the layers are very massive and hard, with practically no porosity, as shown by tests which I have made myself as well as by those made by Prof. Johnson. Below we give three analyses of the Bayport limestone, two of calcareous beds and one of dolomite, and among Rominger's analyses (52, 53) will be found some analyses of the Bellevue quarry of limestone and dolomite. The Bellevue quarry is said to cover 300 acres and to run 90 per cent of lime. Over 200 men are employed in the quarry with two trains a day, and about 700 tons of rock are shipped to Wyandotte, for this quarry is owned by the Michigan Alkali Company (the Fords). The plant is said to have a capacity for crushing 2,000 tons daily. The main building is 44x68 feet, 50 feet to plate, with a power house 30x60 feet. It has its own electrical plant, owns 200 railroad cars of its own and ships about 25 carloads daily to Wyandotte. This stone is there used in the manufacture of soda ash, including baking powder. The soda ash is used in making plate glass. The supply is practically inexhaustible, or at least will give constant employment to a force as large as the present for a long time, it is said. The rock lies only about two feet below the surface and is from 10 to 20 feet thick. Underneath this

* See Rominger's analysis No. 50, below, also article by R. A. Daly in the Journal of Geology Vol. VIII, No. 2, p. 137.
† See Gregory's report.

is a blue rock which, with the refuse from the limestone, is used for macadam pavement. It is said to be rather soft and very dusty for use on city streets.

The limestone is also combined with mud from Detroit river and burned to make Portland cement.

The largest quarry next to the Bellevue quarry, probably larger in fact, one certainly which has been worked vigorously for over a decade, is that at Bayport. The main quarry is on Sec. 5, T. 16 N., R. 10 E., but the limestone upon which it stands extends from section 22 to the lake shore and is also found on North Island of Wild Fowl bay, where a small quarry was opened some years ago. The Bayport stone seems to be, if anything, harder and more massive than at Bellevue. We find the range from limestones which have 90 per cent and over of carbonate of lime to those which are dolomite, as shown in the analyses below.

ANALYSES FROM THE BAYPORT QUARRY.

	I.	II.	III.
Carbonate of lime	91.538	91.32	61.52
Carbonate of magnesia	.944	2.48	14.50
Sand	3.330	4.46	20.85
Clay	.....	.....	2.04
Phosphate of lime	Traces	.....	.09
Bisulphate of iron	1.334	.78	.15
Water	2.854	.95	.85
	100.00	100.00	100.00

The crushing strength as determined at the Watertown arsenal was 26,000 pounds per square inch, the weight 170 pounds per cubic foot and the specific gravity 2.72. I am inclined to think that there is generally less sulphur than at the Bellevue quarry. The material has so far been mainly used for quicklime, macadam and building stone, and I see no reason why it should not make a good blast furnace material, and it must be remembered that it is only a few miles from coal mines.

On the other side of the bay we have extensive exposures of limestone in Au Gres township, and thus northwest. There are a number of half-opened quarries on the line of the Detroit & Mackinac R. R., about three miles southeast of Omer.* Just south of Omer, near Arenac postoffice, an extension of this limestone gave the Dow Chemical Company the following analysis:

Calcium carbonate	94.8
Magnesium "	1.1
Iron, alumina	.9
Insoluble	1.7
Organic matter by difference	1.5
	100.0%

It would seem quite possible that in this region the limestone quarry business might be largely developed since it is convenient to water and not very far from railroads nor from coal, sugar and alkali works. The same limestone occurs in the neighborhood of Grand Rapids, and in fact the ledge makes the rapids from which the city takes its name. The beds have been worked for building stone both on the river and at other points. Many of the older quarries are built over so

* More fully described already by N. M. Gregory, pp. 12-18. Mr. Griffin's quarry is the most extensively opened.

as not to be accessible. As usual a certain amount of sulphide of iron is found. Some of the older quarries are on Davis street, Taylor street and Myrtle street.* Three or four miles south, the limestone is near the surface and contains about 93 per cent of calcium carbonate.

The limestones above this in the coal measures are little known. There are not infrequently bands and nodules of carbonate of iron, but nothing of commercial value has been developed. In fact no practical investigations have ever been made, but if the manufacture of iron were once fairly undertaken in the Saginaw valley, which would be an excellent place for it, I think some attention might be given to these black band ores.

Beside the limestone already described there is one very important form of lime which is generally and rather improperly called marl. The marl of Michigan, which has been eagerly sought for in the manufacture of Portland cement, has more properly been called "bog lime," and might well be called lake lime. It is not at all what is ordinarily known as marl, for there is very little clay in it, and in fact the quality that is sought has practically no clay, but it is a nearly pure carbonate of lime found in the shape of an ooze at the bottom of a great many Michigan lakes. It is nearly white, sticky and slimy, and in that respect differs from calcareous tufa but is quite as pure as tufa. There is usually a small amount of silica, introduced by diatoms or as sand, and a smaller amount of insoluble iron and alumina. There is always considerable organic matter which may be combined directly with the lime. The amount of magnesia varies. The following analysis by Lathbury and Spackman fairly represents the composition of the marl after the water and organic matter are driven off:

Carbonate of lime	96.00
" " magnesia	1.00
Silica	.10
Iron and alumina	.32
Sulphuric acid	.52

The analyses of marl are rather hard to compare on account of the uncertain amount of water and organic matter which will appear in the samples and the different way in which they are treated by different chemists. A certain amount of organic matter appears to be inherent to the marl, and indeed combined with the lime, but another part may be introduced from the layer of peat and muck overlying in the process of taking the sample. The main use of this marl has been in the manufacture of Portland cement, an industry now well established in Michigan which indeed bids fair to be overdone in time. Deposits of marl are very abundant and many of them very extensive and of good quality. It looks as though those plants would survive in the long run which are well situated in regard to market and a suitable coal as well as a marl, and are properly managed. The coal for the manufacture of Portland cement should be of uniform quality and as free as possible from sulphur, and few if any of the surface coals fulfil this condition.

The following groups of marl analyses are furnished by W. M. Courtis, M. E., of Detroit. Many more will be found in Mr. Hale's report on marl:

* See pp. 62 and 65 of the First Report of the Michigan Acad. of Science. C. A. Whittemore.

MARLS.—FROM LAKE SHORE WEST OF GRAND RAPIDS.

(The sample loses 6.376 per cent of water and volatile hydrocarbon when dried at 100 C.)

THE DRIED MARL CONTAINS:

Organic matter	0.790 per cent.
Combined water less org. matter as above	0.235 " "
Silica (no sand)	2.528 " "
Tricalcic phosphate	0.150 " "
Chlorine as sodium chloride	0.119 " "
Alumina and a little iron	0.432 " "
Carbonate of magnesia	1.250 " "
Carbonate of lime to balance	94.496 " "
Sulphur	none " "
	100.000

FROM ALPENA COUNTY, MICHIGAN.

	Per cent.
Carb. of lime	74.48
" " magnesia	0.50
Silica	7.20
Alumina	0.54
Ferric oxide	2.36
Sulphuric acid	0.89
Organic matter	12.88
Water	1.25
	100.00

NEAR GRAYLING, MICHIGAN.*

(Average sample.)

Water lost at 100 degrees	61.
Dried marl	49.

	Per cent.
Moisture	0.60
Organic matter	9.80
Insoluble silica	0.78
Soluble silica	0.13
Ferric oxide	1.13
Alumina	0.07
Calcium carbonate	87.00
Magnesium "	0.91
Sulphuric acid	0.27
	100.69

(Same sample figured without the organic matter is:)

	Per cent.
Calcium carb	97.00
Silica	1.01
Ferric oxide	1.26
Alumina	0.08
Magnesium carb	1.01
Sulphuric acid	0.30
	100.66

CASS CITY, MICHIGAN.

Lime carb	82.1420
Magnesia	4.6200
Iron and alumina	0.9775
Silica	1.1510
Phosphoric acid	0.0370
Sulphuric acid	none
Organic matter	11.1730
Loss on ignition	16.2700

CASS CITY, MICHIGAN.

Lime	89.965
Magnesia	1.672
Iron	0.999
Alumina	0.158
Silica	1.222
Phosphoric acid	¾ lbs. to the ton.
Sulphuric acid	none
Organic matter	5.984
Loss on ignition	9.750

* Another analysis of marl from Grayling is given in the Agricultural College Bulletin, No. 99, p. 11.

ANALYSES BY C. ROMINGER.

		Carbonate of lime—Per cent.	Carbonate of magnesia—Per cent.	Iron, Alumina Hydrate—Per cent.	Residue—Per cent.
Archean dolomite, Vol. I, page 101	1	61	34	1	0.25
Secondary, Vol. I, page 92	2	55	35	5	5
Calciferous, Vol. I, page 79	3	47	38	3	12
	4	54	42	1	2
	5	42	33.6	1	23
	6	45	35	2	18
	7	50	33	2	14
	8	49	32	2.5	15
	9	47	37	0.8	15
	10	47	36	2	15
	11	42	34	0.7	23
	12	52	40	2	6
	13	49	40	5	6
	14	53	39	4	* 3.7
Trenton, Vol. I, page 78	15	52	38.5	3	5.5
	16	88	4	1	6.4
	17	55.8	21	2.4	20.8
	18	90	3	1	4.6
	19	92	2	1	5
	20	51	38	2.5	7
	21	89	2	1.5	8
	22	82	3	1.5	13
	23	47.3	2.5	1.6	48.6
Cincinnati, Vol. I, page 78	24	36	18	4	42
Niagara, Vol. I, page 48	25	56	40	1	1.5
	26	56	43	traces	1
	27	62	33	2	3
	28	54	39	4*	2
	29	58	32	2	7
	30	95	1	2	2
	31	94	2	1	2
	32	52	35	2	9
	33	52	38	3	6
	34	60	32	1	3
	35	59	38	1	1
	36	56.6	39	1	2.5
Salina, Vol. I, page 31	37	53	44	1	2
	38	41	22	7	30

* Almost all alumina.

ANALYSES BY C. ROMINGER—Concluded.

			Carbonate of lime—Per cent.	Carbonate of magnesia—Per cent.	Iron, Alumina Hydrate—Per cent.	Residue—Per cent.
Monroe or Waterlime...	Vol. I, page 29.....	39	46	14	10	30
	Vol. I, page 29.....	40	55	41	4	.....
	....	41	51	37	.....	.....
	Vol. III, page 28...	42	54	42	.....	4
	Vol. III, page 28...	43	46	.....	.....	54
	Vol. III, page 35...	44	59	39	.....	.....
Dundee or Corniferous..	Vol. I, page 29.....	45	68	22	2	8
	Vol. III, page 26...	46	87.5	10.1	.....	2
	Vol. III, page 27...	47	84	13	0.4	2.2
Traverse.....	Vol. III, page 59...	48	58	38	1.5	0.5
	Vol. III, page 60...	49	56	39	2.8	0.4
Antrim (Genesee), Vol. III, page 66		50	89	2	.....	7.5
Michigan.....	Vol. III, page 109..	51	48	27	4	18
	Vol. III, page 113..	51	96	1.0	0.5	1.5
	Vol. III, page 113..	53	56	23	5.5	9.0
	Vol. III, page 115..	54	63.7	11.4	18.4	2.9
	Vol. III, page 116..	55	94	1	1	4
	Vol. III, page 117..	56	96.9	1	0.7	1.4

LOCATION OF SPECIMENS.

1. Specimen of Archean dolomite from Sturgeon river, near the Breen mine, of flesh color and free from silicious seams.
2. Specimen of the more compact kind of dolomite formed from decomposed peridotite, of flesh-red color.
3. Dolomites forming the top stratum of Sulphur Island.
4. Calciferous formations, Grand Rapids of Menominee river, lowest strata above the sand rock of oölitic structure.
5. Variegated limestone, stratum No. 3 of the Grand Rapids section.
6. Upper strata at Grand Rapids of Menominee river.
7. Arenaceous limestone, with *Lingula antiqua,* from Escanaba river.
8. Lowest brecciated limestone, near the forks of the Escanaba river.
9. Dolomite from the forks of the Escanaba river.
10. Falls of Au Train river, calciferous sand rock.
11. Mud lake, three miles south of Au Train river falls, calciferous sand rock.
12. West Anebish Rapids, calciferous dolomite.
13. Calciferous strata on top of the ravine near Munising furnace, Grand Island bay.
14. Calciferous strata from coaling station No. 3 of Munising furnace, pure dolomite stratum.

15. Dolomites forming the upper beds of the Trenton group, at the mouth of the Escanaba river.
16. Wedge-shaped limestone of the Escanaba river, next following the former dolomites.
17. Fossiliferous, shaly and arenaceous limestone, next below the wedge-shaped limestone of the Escanaba river.
18. Limestone containing *Orthoceras proteiforme* of the Escanaba river.
19. Lowest beds of the Trenton group on the Escanaba river, containing Cyrtodonta.
20. Dolomite of the Trenton group on Whitefish river, two miles above the saw mill.
21. Upper limestone of Encampment b'Ours, with *Orthoceras proteiforme.*
22. Blue limestone with smooth conchoidal fractures, forming the middle strata of the Trenton group on St. Joseph's Island.
23. Lowest sandy beds on St. Josephs, containing Cyrtodonta shells.
24. Argillaceous limestone from the Hudson river group of Bay de Noquette.
25. White crystalline dolomite from the middle division of the Niagara group from the Lake Huron shore, one mile east of Pine river. This is typical Guelph dolomite.
26. Light gray colored dolomite from the middle division at Point Detour on St. Mary's river.
27. Dolomite forming the top stratum at Marblehead, Drummond's Island.
28. Upper part of Marblehead quarry of laminated structure with absorbent earthy structure.
29. Lower beds of Marblehead quarry, Drummond Island.
30. Limestone from the section of Marblehead with acicular cavities (vide description below).
31. Limestone from the Marblehead section, 30 feet below the acicular limestone, described as nodular bituminous limestone containing fossils.
32. Lowest beds in the Marblehead section.
33. Loose slab on the west side of Sitgreaves' bay, immediately above the Hudson river group strata, Drummond's Island.
34. Quarry Point on the west side of Drummond's Island, quarry stone of laminated structure.
35. Sole bed of the same quarry of more crystalline structure than specimen No. 10.
36. Lowest strata of Burnt Bluff of Big Bay de Noquette. The white marble-like masses embedded between them are almost chemically pure $Ca\ CO_3$.
37. Dolomite in the bed of Carp river.
38. Variegated marl of St. Martin's Island.
39. Dolomite from gypsum quarries of Point aux Chênes.
40. Exposure on the east side of Mackinac, close to water level.
41. Oölitic dolomite from Plum creek.
42. Compact dolomite rock mottled with light and dark blue cloudy specks. Sec. 16, Ida township, Monroe county.
43. Calcareous sandstone, same quarry two miles west of Ida.

44. Dolomite with acicular crystals.
45. Blanchart's farm, Mackinaw.
46. Principal quarry stone of the Helderberg group, Macon river, Christiancy quarry.
47. Better quarry stone of the Helderberg group, Macon river, Christiancy quarries.
48. Khagashewung Point dolomite.
49. Norwood dolomite.
50. Concretions of granular limestone structure, from the shales of Norwood.
51. Non-fossiliferous portions of rock at the Grandville quarries.
52. Bellevue limestone.
53. Brown dolomite rock of the Bellevue quarries.
54. Brown cellulose dolomite rock, a short distance northeast of Parma village.
55. On Mr. Shoemaker's land, in Summit township, three miles south of Jackson.
56. Limestone of Portage river.

STRATIGRAPHY OF THE TRAVERSE GROUP OF MICHIGAN.

BY AMADEUS W. GRABAU.

21

STRATIGRAPHY OF THE TRAVERSE GROUP OF MICHIGAN.

BY AMADEUS W. GRABAU.

INTRODUCTORY.

The field work on which the following account of the Traverse group of Michigan is based, was done in the late summer of 1900 and during a part of the field season of 1901. Ten days were spent in 1900 in the Alpena region in company with Mr. W. F. Cooper of the Michigan Geological Survey, and four weeks in 1901 (July 20 to August 21) in the Alpena and Petoskey regions in company with Mr. H. W. Shimer, assistant in Palæontology in Columbia University, New York city. The field investigations during the first season were carried on under the auspices of the Geological Survey of Michigan and with the cooperation of the State Geologist, Dr. A. C. Lane; those of the second season, under the same auspices, with additional cooperation of the Geological Department of Columbia University, this department defraying Mr. Shimer's field expenses. The work in the Alpena region during both field seasons was greatly facilitated by the active interest of several prominent Alpena citizens. Foremost among these is Mr. W. H. Johnson, who almost daily assisted us in our work, and whose intimate knowledge of the region enabled him to either personally conduct us, or direct us to the important outcrops of fossiliferous beds. It is but fitting that we should express our personal thanks to Mr. Johnson, for the many courtesies he showed us, in addition to calling attention to the efficient manner in which he has aided the prosecution of the work carried on for the State. Mr. Monaghan of the Alpena Portland Cement Company and Messrs. F. M. Haldeman, superintendent, and L. H. Ludlow, chemist, of the cement company, also put us under obligation by furnishing us with analyses of the various limestones and clays. Mr. Ludlow's lively interest in our investigations, and his constant readiness to aid us, is one of the pleasant recollections of our field experiences. Capt. John D. Persons of the Thunder Bay Island life saving department showed us numerous courtesies during our examination of that and the neighboring Sugar Island, during which time we were his guests. To all these gentlemen our sincere thanks are herewith tendered.

PREVIOUS WORK.

The work of only a few investigators in this region need be noted in this connection.[1] In his report of 1860, Professor Alexander Winchell

[1] In 1823 Dr. J. J. Bigsby read notes on the Geography and Geology of Lake Huron before the London Geological Society, in which the Presque Isle and Middle Island limestone is described, p. 201, as well as that about Mackinac, p. 194, and those on the north side of the lake.

devoted three pages to the Hamilton group of Michigan. In 1866 he issued his report on the Grand Traverse region, in which he devoted less than ten pages to the Hamilton group. On the accompanying map he gives eight localities where typical exposures may be seen. Frequent reference to this report will be made in the discussion of the Petoskey region. Later, in the same year, appeared an appendix to the report on the Grand Traverse region, by the same author. In this pamphlet of fifteen pages he gives a correlation of the various beds described previously, and a table showing the vertical distribution of the various species. He furthermore gives brief descriptions without illustrations of sixty-two species of fossils not before recognized. The illustrations prepared to accompany this report were never published.

In 1875, Professor N. H. Winchell[2] published a brief account of the region of Cheboygan and Old Mackinac. He gives a succession of the beds of this region, with incidental mention of the Alpena region. In 1876 (Proc. Am. Ass. Adv. Sci., II, 57-59) the same author gave a brief account of the parallelism of Devonian outcrops in Michigan and Ohio. In both these papers the Dundee and Lower Traverse beds were referred to the waterlime, on account of the lithologic similarity.

In the Report on the Geology of the Lower Peninsula of Michigan, Dr. Carl Rominger[3] gives the most complete account of the Hamilton or Traverse group of Michigan theretofore published. Twenty-six pages of the report are devoted to the Hamilton group, all the most important outcrops on both sides of the Peninsula being described. Notes are also given on prominent intermediate localities. In the second part of the volume, which is devoted to the description of fossil corals, Rominger describes a large number of species, many of them new, from the Traverse beds of Michigan.

Dr. Lane, in 1895 (Geol. Surv. Mich., Vol. 5, pt. II, the Geology of Lower Michigan with Reference to Deep Borings, p. 24), gives a brief account of the Traverse group, in which he proposes to change the name Little Traverse, employed by Winchell, to Traverse group. The numerous sections given at the end of the volume give the thickness and relative position below the surface of these beds in various parts of the State. A brief record of the Churchill well in Alpena was published by Lane in 1899.[4]

My own studies of this region began in 1900, when I made a brief examination of the Alpena region, the result of which is embodied in a report published in the American Geologist, Vol. 28, pp. 177-189, for September, 1901, under the title of "A Preliminary Geologic Section in Alpena and Presque Isle Counties, Michigan." The second season's work consisted in examining certain of the 19 localities of 1900 and of the study of 32 additional ones, making a total of 51. While a considerable number of localities still remain unexamined, it is nevertheless believed that enough has been done to permit of a preliminary analysis of the Traverse group of Michigan. The complete analysis must, of course, be preceded by a careful study of additional localities and of the fossils

[2] Twelfth Annual Report of the State Board of Agriculture, Mich., for 1873, pp. 103-107. The report is dated 1871.

[3] 1876. Geol. Surv. Mich., Vol. 3.

[4] Engineering and Mining Journal, Nov. 4, 1899, p. 548 after a visit the previous winter, in which I visited the quarries and collected some of the records herein contained. See also my U. S. G. S. water supply papers Nos. 30 and 31.—L.

collected, a work which will require some considerable time. The list of species given in this report for the various beds in each locality include only the common or more readily recognized types. In general these may be considered the type fossils of the beds described, although it will be observed that many of these species have a wide vertical range. The preparation of an exhaustive report on the Palæontology of the Traverse group of Michigan has been begun, and it is hoped that the vertical range of at least the majority of species may be determined. The conclusions herein given, in so far as they depend upon palæontologic research, must be considered as tentative and subject to modification, should the final studies of the fauna demand it.

DESCRIPTION OF LOCALITIES.

A. Alpena (Thunder Bay to Presque Isle) Region.

During the first season's field work a north and south section was prepared extending northward from Alpena. An account of this was published with brief descriptions of 19 localities along the section,[5] and this account, together with additional notes, is here included.

As no topographical map was available, the profile of the country along the section had to be prepared in the field, at the time the geological data were collected. Distances were measured by means of a cyclometer attached to the bicycle, which was the only conveyance employed in the field. To eliminate errors due to unevenness of the country and to other causes, the cyclometer readings were checked by special readings on the section lines. Elevations were obtained by reading the aneroid barometer at all the stations, as often as these stations were passed, and correcting these readings by the barograph record obtained from a stationary instrument at Alpena. Owing to the length of the section, the barograph corrections did not always prove satisfactory, especially as several severe atmospheric disturbances affected the aneroid in the northern part of the section, which were felt to a less degree at Alpena, where their record was obtained by the barograph.

LOCATION AND EXTENT OF THE SECTION.

The section is located in Alpena and Presque Isle counties, Michigan. It runs north from the city of Alpena along the meridian of 83° 25′ longitude west of Greenwich, and forms the western boundary of the eastern third of range 8 E. It extends through the whole of township 32 and 33 north and parts of townships 31 and 34 north. The total length of the section is nearly eighteen miles, but the distance covered in its preparation was nearly double that.

The section is interrupted near the middle by Long lake, and it passes by the eastern end of Grand lake. It strikes the shore of Lake Huron about four miles southeast of Presque Isle light. About one half of the line of the section is along a north-south road.

[5] Loc. cit. for these localities consult the map Pl. VII.

TOPOGRAPHY OF THE SECTION.

In the following table the distances between stations as calculated from the cyclometer readings are given. The elevations given are calculated from the aneroid readings and corrected by the barograph readings. The resulting elevations are those of the various stations above the mean level of Lake Huron, which is taken as 580 feet above the sea.

Station, number and location.	Distance between points. mi. — yds.	Elevation above Lake Huron. (580 ft. A.T.)
1. Thunder Bay	.....	00.0
2. Round House	2.2 — 66	27.7
3. Sec. 15, N. E. Cor.	.2 —110	40.7
4. Sec. 10, E. line base of terrace	.8 — 66	44.4
5. Sec. line top of terrace	.0 —110	56.4
6. Sec. 10, N. E. Cor.	.1 — 22	59.4
7. Sec. 3, E. line, base of terrace	.2 —110	52.1
8. Section line top of terrace	.1 — 88	62.1
9. Sec. 3, end road running west	1 —	67.1
9a. Offset on same, top of terrace	.1 —	79.1
10. Sec. 3, E. line, base of terrace	.1 — 66	62.5
11. Section line top of terrace	.1 —	72.8
12. Sec. 3, E. line top terrace	.6 — 88	85.8
13. Sec. 3, N. E. corner, road running west	.19—132	92.8
14. Sec. 34, E. line	.7 — 44	93.5
15. Sec. 35, W. line	.1 —132	163.5
16. Sec. 34, N. E. corner	.0 —154	119.9
17. Sec. 27, E. line top of terrace	.0 — 88	128.9
17a. Sec. 27, outcrop	.0 — 88	128 9
18. Sec. 27, E. line, base of terrace	.1 —154	120.2
19. Section line, outcrop	.1 —110	124.2
20. Sec. 26, W. line	.1 —132	134.2
21. Sec. 27, E. line, base of terrace	.2 — 44	124.2
22. Section line outcrops	.4 —132	119.2
23. Sec. 22, fork roads	.2 — 88	125.2
24. Sec. 22, centre north line	.7 — 88	117.9
25. Long Lake	.8 —110	110.6
24a. Hell creek bridge	.2 — 22	100.6
25a. Sec. 23, north line, center	.5 —132	106.4
26. Road east of Long Lake	1.2 —154	121.4
27. Sec. 3, E. line	1.1 — 66	125.2
28. Sec. 3, end road running west	.4 — 00	113.0
29. Sec. 3, E. line	.0 — 88	126.0
30. Sec. 3, E. line, top of ridge	.6 — 44	136.8

Station, number and location.	Distance between points. mi.—yds.	Elevation above Lake Huron. (580 ft. A.T.)
31. Town and county line	.0 — 88	136.8
32. Sec. 34, E. line, top of moraine	.6 — 00	134.8
33. Sec. 35, W. line, Rabiteau's farm	.2 —110	112.6
34. Sec. 27, E. line, base of terrace	.3 — 00	81.6
35. Sec. 22, E. line, road running west	1.3 — 22	63.4
36. Fork of roads	.1 — 88	76 4
37. Lake Huron at Bell	.1 —132	32.4
38. Grand lake at Lumber mill, Sec. 15, N. E. corner	1.4 —154	56.2
39. Top moraine, Grand Lake	3.8 — 00	41.7
40. Grand Lake isthmus	.2 — 44	11.7
41. Top gravel ridge, Club house	.1 —132	25.1
42. Kaufman's	.2 — 88	31.1
43. Lake Huron at Presque Isle Light	5.22— 00	33.6

Of the stations here recorded, Nos. 1 to 23, and Nos. 27 to 35, are on the section line; the others are either to the east or the west of the section line. From these data, the accompanying profile of the section (Plate VII) has been constructed.

From a careful plotting, it appears that Long lake and Grand lake lie along the outcrops of shale beds of considerable thickness. The valleys of these two lakes, therefore, which extend along the strike of the strata, represent longitudinal lowlands, carved by streams of the subsequent type out of the softer strata.

From an inspection of the section it will be seen that it crosses a number of terraces of gentle southward and steep northward descent, separated by lowlands of greater or less extent. The greatest of these lowlands is occupied by Long lake and Grand lake, while others are occupied by streamlets. The terraces and accompanying lowlands may be traced northwestward and southeastward along the strike of the strata, the former marking the outcrops of the resistant strata, while the latter mark the softer beds. In a number of cases the northeastern face of the terrace is an abrupt cliff, a good example of which is shown on the south shore of Grand lake. The topographic elements thus produced are a series of minor cuestas (W. M. Davis) and lowlands, such as are normally developed in regions made up of nearly horizontal strata of alternating hardness. From the soundings of the Lake Survey Charts it becomes evident that a cuesta of considerable magnitude, formed by the lower strata of this region, can be traced across Lake Huron from a little east of Presque Isle to the Canadian shore above Goderich.[6]

Similar alternations of terrace and lowland are found south of Alpena, though they are in general less pronounced. One or more of the lowlands is followed by Thunder Bay river in portions of its course.[7]

[6] See Grabau, Bull. N. Y. State Mus. No. 45, p. 54.

[7] It may be noted that the direction of general ice advance is such that the shock and lee sides would nearly harmonize with preglacial structural forms.—L.

TOPOGRAPHY OF THE SHORE LINE.

The shore line in this portion of the peninsula is generally low and not infrequently swampy. This is especially true of the Thunder bay region south of Alpena as far as Partridge Point, at which place bluffs about 12 feet in height front the lake. At only one locality between Alpena and Partridge Point are rocks exposed along the shore. This is at Stony Point, immediately south of Alpena, where low ledges, generally submerged, appear on the lake shore. No rock exposures have been observed along the north shore of Thunder bay except in the eastern-most portion. Here Thunder Bay Island and Sugar Island show ledges, though the relief is very slight. Rock cliffs are found at the head of Misery or Little Thunder bay, forming the walls of a large sink hole. Other ledges occur at intervals along the shore; most of these, however, are low, or even submerged. The northeast shore of Presque Isle and False Presque Isle extend along the strike of a resistant limestone bed (Dundee), which, however, does not rise into cliffs. The same bed probably forms the eastern shore of Middle Island.

The strike of the strata of this region is approximately northwest and southeast. The dip is 42 feet to the mile, toward the southwest. This is equivalent to 30 feet to the mile along the line of the section.

STRATIGRAPHY OF THE EASTERN (ALPENA) REGION.

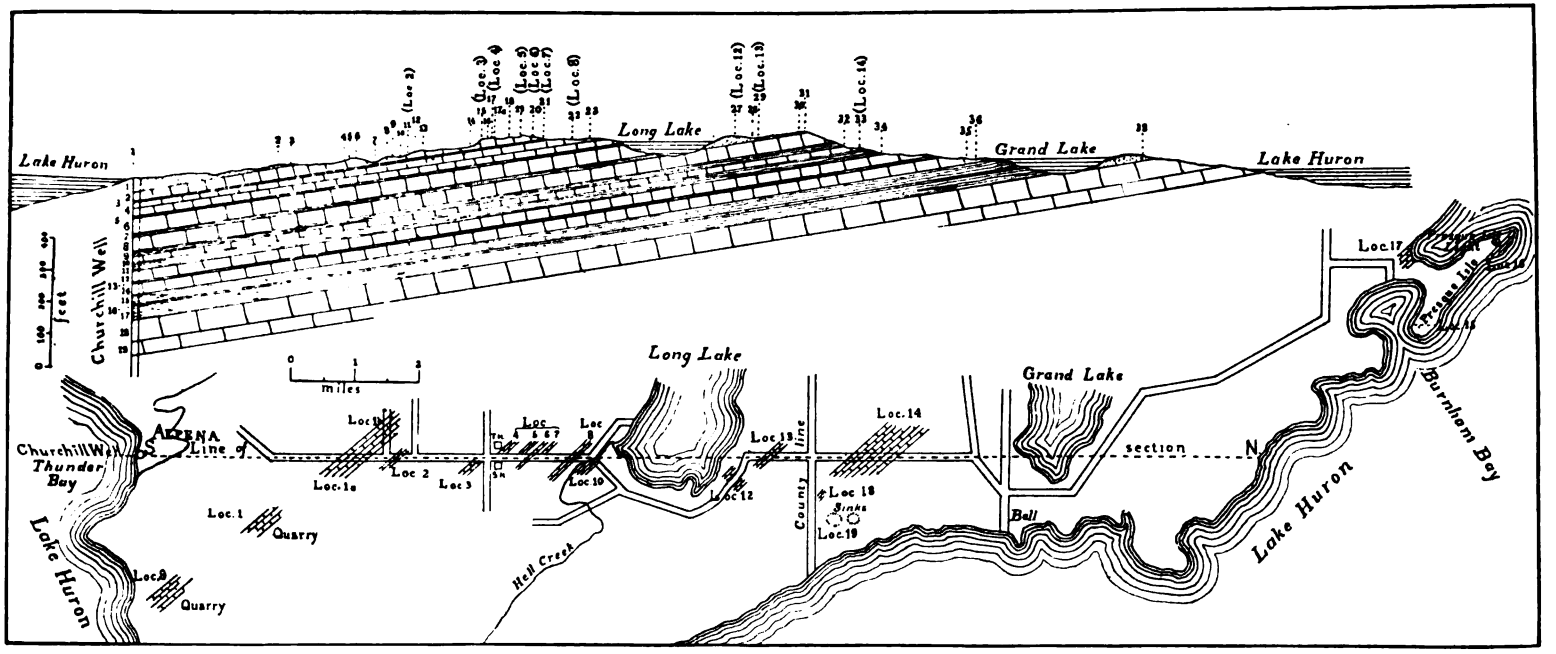
A. Well records.

Owing to the extensive drift coverings of this region, rock exposures are comparatively rare, and are confined to roadside cuttings, quarries and the few natural exposures, which are found along the tops of the terraces and on the shore. From well records, however, we gain a knowledge of the succession of beds, and of the thickness of the various members. Taking this as the foundation of the stratigraphic work for this region, we may attempt a correlation of those beds which crop out on the surface, with those recorded in the well. Lithic characteristics will have to be relied upon in such a correlation, and for the area covered by this section, these may be considered reliable. This is especially the case, since all the strata entering into the section are off-shore deposits, with a minimum of coarse detritus, and hence of a character which remains uniform over a large area.

The following succession of strata in this region has been derived from the records of the Churchill well, the location of which is near the southern end of the section in Alpena.[8]

The mouth of the well is near the level of Lake Huron, and above the coral limestone of Alpena. This rock, which will be called the Alpena limestone, is the middle member of the Traverse (Hamilton) group of Michigan, and hence the entire upper portion of this group is unrepresented in the well record. At a depth of 1267 to 1278 feet, the well ends in the salt beds of the Salina group, having penetrated the entire lower Devonic and part of the upper Siluric rocks of the region.

[8] Geol. Surv. Mich., Vol. V, p. 87. See also p. 68.



Bed 1 - sand and gravel.
Bed 3 - thin shale bed
Bed 5 - " " "
Bed 13 - " " "
Bed 16 - thin limestone bed

GEOLOGIC SECTION IN ALPENA AND PRESQUE ISLE COUNTIES, MICH.

(I.) Succession of strata in the Churchill well at Alpena, Mich.:

		Feet.	Depth.
1.	Sand and boulders	41.0	41.0
2.	Hard white (light colored) limestone	25.0	66.0
3.	Shale	9.0	75.0
4.	Very hard white limestone	49.5	124.5
5.	Shale	2.5	127.0
6.	Extra hard gray limestone	40.0	167.0
7.	Blue shale	20.0	187.0
8.	Hard white limestone	34.0	221.0
9.	Shale, 7 feet white and slimy, possibly gypsum (?)	18.0	239.0
10.	Hard white limestone	23.0	262.0
11.	Very sticky blue shale	27.0	289.0
12.	Hard white limestone	32.0	321.0
13.	Shale	3.0	324.0
14.	Hard white limestone, upper two-thirds extra hard	39.0	363.0
15.	Shale	24.0	387.0
16.	Hard white limestone	5.0	392.0
17.	Shale, mostly blue	52.0	444.0
18.	Hard white and gray limestone, mostly extra hard	60.0	504.0
19.	Extremely hard (flinty) limestone	39.0	543.0
20.	Shale	25.0	568.0
21.	Hard gray and white limestone	103.0	671.0
22.	Shale	20.0	691.0
23.	Hard white limestone	86.0	777.0
24.	Sandy lime and shale	10.0	787.0
25.	Hard white limestone	480.0	1267.0

This carried the drill down to the rock salt of the Salina group.

Strata 15 to 17 are provisionally considered the equivalent of the New York Marcellus, though there is no evidence at present to indicate that the faunal characteristics, on which the separation of the Marcellus beds alone rests, are found in this region. For this reason it is perhaps better to speak of these beds as the lowest Traverse shales, regarding the five-foot stratum of limestone (No. 16) as an integral part of the series. The total thickness of this lowest shale series, which are below referred to as the Bell shales, is therefore 81 feet.

Strata 18 and 19 are provisionally referred to the Dundee[9] limestone, which is considered the equivalent (approximately) of the Onondaga limestone series of New York. The combined thickness of the two strata referred to this formation is 99 feet.

Stratum 21 probably represents the Mackinac limestone, a formation which is believed to be the time equivalent of the Manlius limestone of New York. It undoubtedly is of upper Siluric age, but the determination of its exact equivalency must be deferred until paleontologic investigations are made. The beds below it, belong, in part at least, to the same horizon.

Whether the shale of stratum 20 belongs to the overlying or underlying formation is likewise an unanswered question.

If the above correlations are correct, the Churchill well record gives us the following thicknesses of Devonic formations:

Traverse upper shales	Not represented
Traverse middle limestone (Alpena limestone)	25
Traverse lower shales and limestones	378
Total middle and lower Traverse	
Dundee limestones	
Total	

[9] They yield freely water charged with H_2S.

(II.) Well of Alpena Portland Cement Company:

On the land of the Alpena Portland Cement Company (Loc. 9) a well was put down in search of water, within the last year. I had the opportunity to examine the samples of this well through the courtesy of the officers of the cement works. The following record was obtained from samples taken at two-foot intervals:

Character of rock.	Formation.	Thickness.—Feet.	Depth.—Feet.
Pure white limestone of very uniform character	Alpena limestone	34	34
Gray shale appears and increases in amount down to 50 feet, then it decreases again	Long Lake limestone & shales	20	54
Gray and black shales predominate, often bituminous	"	22	76
White limestone again abundant	"	02	78
Black and gray shales abundant, then decrease to 82 feet	"	04	82
White limestone predominates. Shale in small quantity	"	02	84
Missing	"	04	88
Gray calcareous shale in small quantity with white limestone	"	02	90
Gray calcareous shale and gray limestone	"	02	92
Missing	"	20	112
Gray shales abundant with white limestone	"	04	116
Nearly pure grayish limestone	"	02	118
Gray shale increases	"	04	122
Mostly gray calcareous shale	"	04	126
White limestone with small quantity of gray shale	"	02	128
Gray shale somewhat more abundant, mostly white and gray limestone	"	02	130
Gray shale increasing to about equal quantity with limestone	"	06	136
Mostly gray calcareous shale, very little white limestone	"	02	138
Limestone more abundant	"	02	140
About equal amounts of gray shale and white limestone	"	02	142
Acervularia	"	02	144
Gray crystalline limestone	"	02	146
Gray limestone with some gray shale	"	02	148
Gray shale with gray and white limestone	"	02	150

This record does not seem to correlate at first very readily with that of the Churchill well. The Alpena limestone here has a thickness of 34 feet, and since this rock on Dock street is overlain by shales (Dock street clay), the total thickness of the Alpena limestone is probably in the neighborhood of 35 feet, instead of 25, as shown in the Churchill well. After this follows 20 feet of calcareous beds in which there is a considerable quantity of gray shale, probably in the form of thin intercalated beds. A part of this at least is to be correlated with the shale

bed (No. 3) nine feet in thickness recorded in the Churchill well. The rest, with the 22 feet in which gray and black shales predominate, correspond to what in the Churchill well record has been called limestone. The shale is probably in thin layers and so would not attract the attention of the drillers, who would regard all the strata as limestone.

(III.) Wells of Alpena Business Men's Association, Frank J. Jahncke, driller:

No. 1. On north line of Sec. 22, T. 30 N., R. 8 E., close to the shore and not eight feet above it.[10]

The section is south of the western end of Partridge Point and gives the following succession:

Description of rock.	Formation.	Thickness.—Feet.	Depth.—Feet.
Black shale	Neo-Devonian black shale (Antrim)	50	27-29
" "	"		47-49
" "	"		49-57
" " and greenish argillaceous limestone	"		67-69
Buff dolomite?	Upper Traverse shale and limestone.	48	77-79
" "	"		85-89
Dark bluish shale or limestone	"		97-99
Buff limestone	"		104-109
Coarse varicolored limestone	"		123-125

No. 2. This is half a mile south of No. 1, near the center of Sec. 22. The record is as follows:

Description of rock.	Formation.	Thickness.—Feet.	Depth.—Feet.
Black shale	Antrim black shale	75-80	76
Gray shale	Upper Traverse shales		83

[10] The Survey has alternate bottles of samples, the others being retained by Mr. Monaghan of Alpena.

(IV.) Well of C. Moench & Sons Company, T. 31 N., R. 8 E., Sec. 28:

This is in the southwestern portion of Alpena, a mile or more southwest from the line of strike of the rocks exposed in the Churchill well. The following brief record is preserved. The drilling occurred in February, 1899:

Description of rock.	Formation.	Thickness.—Feet.	Depth.—Feet.
Quicksand		80	80
Shale and rock	Traverse group	360	440
Balance rock	Traverse&Dundee gr.	210	650

Although the record does not state so, the drilling probably commenced at the summit of the middle limestone bed (Alpena limestone). The 80 feet of drift in this well, taken in connection with the 41 feet of drift in the Churchill well, suggests that Alpena is underlain by a preglacial valley—that of the Lower Thunder Bay river—which is of the normal consequent type, and opened out in a bed of soft shale, similar to Long and Grand lakes. This old valley appears to have had as its floor the resistant Alpena limestone, which gradually rises to the northeast and comes to the surface a mile or more northeast, i. e., across the strike of the strata, from the Churchill well. The position of this limestone is thus obtained at three points: at the Churchill well, a mile or more northeast of this, and a mile or more southwest of the well. At the northeasternmost point, i. e., Loc. 1, the limestone comes to the surface. At the Churchill well it is 41 feet below the surface. In Sec. 28 it is apparently 80 feet below the surface, while the surface of the well is probably but little above the level of the lake. This gives approximately 40 feet to the mile as the dip of the limestone, which is nearly the ascertained dip of the rocks in this region.

At Stony Point rock appears on the surface, where the point is formed of resistant limestone layers. Other outcrops are found at Warner's brickyard (Loc. 25), which lies northwest from Stony Point. It thus appears that these beds are at least 80 feet above the Alpena limestone, and that the Stony Point beds form the edge of an ancient escarpment (inface of a cuesta) the valley in front of which is drift-filled to a level with the top of the cliff.

(V.) Tannery well:

In Sec. 22, T. 31 N., R. 8 E., a well was put down in November, 1892, to a depth of 625 (?) feet, by the Northern Extract Company. This struck water in good quantity at a depth of about 400 feet, where a soft shale rock was found, which greatly impeded the drilling. This well is essentially along the strike of the rocks from the Churchill well, and it is probable that the bed of shale here referred to is the Bell Shale (see beyond), out of which the valley of Grand lake is carved. This shale at the Churchill well lies about 360 feet below the surface.

(VI.) Well No. 6.[11] Put down to salt at 1164 feet, before 1866, near the electric light works.

[11] Geol. Surv. Mich., Vol.V, p. 47.

(VII.) Rominger[12] speaks of a similar well put down in 1872 close to the bed of Thunder Bay river. The borings commenced in limestones and continued without much interruption by other beds to a depth of 400 feet, where blue shales 80 feet in thickness were struck, and a powerful stream of water, for which this formed the impervious bed, rose to the surface, carrying with it many of the characteristic fossils of the lower beds. These Rominger supposed to have come from the shales, but since they abound in the overlying beds it is more probable that they were derived from these.

(VIII.) Fletcher well. Paper mill on Fletcher street, Alpena, Mich. A. J. Scott, driller. March, 1901. Fifteen feet above lake, 595 A. T.:

	Description of rock.	Thickness, feet.	Depth, feet.
1.	Surface sand	32.0	32.0
	Drive pipe (end of Pleistocene)		32.8
2.	Gray limestone	20.0	52.0
3.	Limestone and shale	28.0	80.0
4.	Gray limestone	40.0	120.0
5.	Dark limestone	40.0	160.0
6.	Brown shale	5.0	165.0
7.	Light and dark limestone with streaks of shale	85.0	250.0
8.	Soft shale (soapstone)	80.0	330.0
9.	Limestone with shale streaks	20.0	350.0
10.	Gray limestone	10.0	360.0
11.	Slate (soapstone)	82.0	442.0
	Casing 6¼ inches to		450.0
12.	Gray limestone	43.0	485.0
	First flow at		490.0
13.	Brown sandy limestone	55.0	540.0
14.	Very hard brown limestone which cuts bits badly, but is said all to dissolve in muriatic acid	15.0	555.0
	Second flow at		615.0
	Slightly sulphureted head to 40 feet above lake level, flow 600 gallons per minute.		
14a.	Same as 14	80.0	635.0
	End of Corniferous or Upper Helderberg.		
15.	Gypsiferous limestone	7.0	642.0

In this well the Alpena limestone appears to be only 20 feet thick, though it is probable that the record is not as accurate as preceding ones. Stratum 8 of this well probably corresponds to stratum 11 of the Churchill well, but the thickness in the Fletcher well (80 feet) is probably given as too great. Stratum 11 of the Fletcher well corresponds to strata 15 to 17 inclusive in the Churchill well, and represents the basal shale series, i. e., the Bell Shale.

It is not improbable that the "coarse, varicolored limestone" met with at a depth of 123 feet in the Business Men's Association well No. 1 (III-1), south of Partridge Point, is the stratum cropping out at Stony Point. If this is the case, the total thickness of the shales between this stratum and the base of the Black Shale is, according to the interpretation of the well record, 46 feet. This is not inconsistent with the dip of the strata. Adding to this thickness the 80 feet of strata between the Alpena limestone and the Stony Point beds, we have a total thickness of 126 feet, or, in round numbers, 130 feet for the upper shales and limestones of the Traverse group of Thunder bay. If this is correct, the Traverse group of this region admits of the following subdivision:

[12] Geol. Surv. Mich. Vol. III, Part I, 1876, p 40.

3.	Traverse upper shales and limestones, or Thunder Bay series (minimum estimate)	130 feet
2.	Traverse middle limestone or Alpena limestone	35 "
1.	Traverse lower limestone and shale—	
	B. Long Lake series	298 "
	A. Bell Shale	80 "
	Total	543 feet

Rominger estimates the total thickness of the Hamilton group of Thunder bay to be about 580 feet (p. 40). The total thickness of the upper or Thunder bay series is probably somewhat more than 130 feet, and may even reach 170 feet, in which case Rominger's estimate of the total thickness is the true one. The distance measured in a straight line across the strike from the point of outcrops of the top of the middle limestone at lake level to the first appearance of the Black shale at the lake level, would give about 200 feet for the thickness of the shales overlying the Alpena limestone, assuming that the dip of the strata remains a constant one, i. e., 42 feet to the mile. Rominger's estimate may, therefore, be regarded as probably a close approach to the truth. Still his division of 100 feet for the upper beds and 480 feet for the lower is not borne out by the more accurate records of the recent well borings.

B. Records from outcrops.

For the detailed description of the strata of this region the Alpena limestone makes the most convenient reference stratum, and as it is also the most important member of the group from an economic standpoint, it will be described first. Following it will be given descriptions of the lower members of the group, in their stratigraphic order, from the highest to the lowest beds. The upper Traverse or Thunder bay series will be described last, as least exposed. It will be observed that the field localities do not regularly succeed one another, since it was most convenient to study the localities without direct reference to succession. The localities of the Alpena region are here given in succession:

Loc. 1.	Quarries N. E. of Alpena. (Owen Fox and Richard Collins)	Alpena limestone.
2.	Outcrop two miles N. of Alpena, Long Lake Road (Sec. line sta. 11)	" "
3.	Long Lake Road (Sec. line sta. 15)	" "
4.	Section line sta. 17a	" "
5.	Section line sta. 19	Long Lake series.
6.	" " " 20	" " "
7.	" " " 21	" " "
8.	" " " 22. Forks of road south of Long Lake	" " "
9.	Quarry Alpena Portland Cement company	Alpena limestone.
10.	Hell Creek Fall (sta. 24)	Long Lake series.
11.	Bell Road (sta. 26)	" " "

Loc. 12.	Bell Road (sta. 27)	Long Lake series.
13	Bell Road (section line sta. 29)	" " "
14.	Rabiteau's farm (section line sta. 33)	" " "
15.	Burnham Bay	Dundee limestone.
16.	Presque Isle Light	" "
17.	Mainland south of Presque Isle	" "
18.	Presque Isle county, S. E. of Loc. 14	Long Lake series.
19.	Sink holes sec. 36 R. 8 E., T. 33 N	Bell shales at base of 19.
20.	Misery Bay	Long Lake series.
21.	Fletcher Dam	Upper Traverse beds or Thunder Bay series.
22.	Stony Point	"
23.	Partridge Point	"
24.	Boom Company Dam	"
25.	Warner Brickyard	"
26.	Thunder Bay Island	Lower Alpena limestone.
27.	Roadside sec. 27 R. 8 E., T. 32 N	Long Lake series.
28.	¼ mile N. E. of preceding	" " "
29.	Wiesey's well	" " "
30.	2 miles S. of Clay Pits	" " "
31.	Clay Pit Alpena Portland Cement company	" " "
32.	Same as Loc. 8	" " "
33.	Long Lake Road North of preceding	" " "
33a.	N. E. of 32	" " "
34.	Long Lake road near lake	" " "
35.	Under root of tree near sink holes (Loc. 19)	" " "
36.	False Presque Isle	Dundee limestone.
37.	Grand Lake Ledges	Lowest Long Lake beds.

ALPENA LIMESTONE.

This limestone underlies a considerable area to the north and northeast of Alpena. It appears on the surface in the northeastern portion of the town where several quarries are opened in it (Loc. 1). It is also quarried in the cement-works quarry less than a mile east of the town, near the lake shore, or approximately southeast of the preceding locality. This is designated Loc. 9.

The rock first appears on the section line, about a mile north of the town (Sta. 4). It appears at intervals to the north of this, and is prominently exposed in the terrace which crosses the section line in a direct northeast line from the quarries. (Sta. 8).

This terrace continues northwestward and furnished another good exposure of the limestone about a tenth of a mile west of the section along the first west road. (Sta. 9a, Loc. 1b.)

Loc. 1. Quarries northeast of Alpena. The limestone is here almost wholly composed of corals and hydro-corallines, though brachiopods and other organisms are not wanting. The corals are Favosites and Acer-

vularia, the former probably represented by a number of species. Large masses of the rock are entirely made up of these corals, which appear to be still in the place where they grew. Other large masses of the rock are composed of the hydro-coralline Stromatopora and allied genera, which also appear to be represented by several species. Among the smaller corals, species of Zaphrentis, Aulopora, and Ceratopora predominate, while the Bryozoa are chiefly represented by fenestelloids, and Lichenalia-like types. The chief brachiopods are: *Atrypa reticularis* (an extremely convex form), *Spirifer* cf. *S. mucronatus,* Stropheodonta, several species, *Cyrtina umbonata* var *alpenensis, Gypidula romingeri,* etc.

The central mass of limestone of this region has all the characteristics of an ancient coral reef in which the chief reef-builders were the Favosites, Acervularias, and Stromatoporas. These formed the main mass of the reef, while between them grew the smaller species, and the other organisms which go to make up the *ensemble* of the reef population. A careful examination of sections in the quarries shows that there is an absence of stratification and regularity of structure in general, within the reef portion of this limestone. This is to be expected, since this portion of the mass is entirely of organic origin. In form, this portion is dome-like, and the stratified beds of limestone which flank it, dip away from it in all directions at an angle exceeding that of the normal dip of the strata of this region as shown by the following figure:

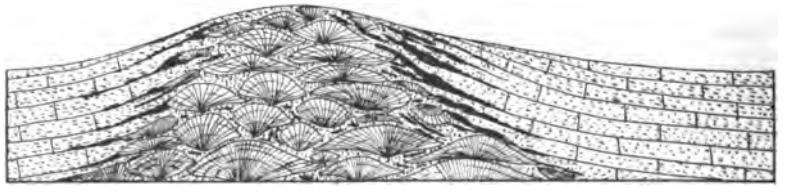


Fig. 2. Cross section of the coral reef in Collins' Quarry, Alpena, showing the reef portion, the flanking layers of coral sand limestone and the interfingering of the two. The dips are actually observed.

a. Owen Fox's Quarry:

In this quarry the general dip of the strata is 4 degrees to the southwest. In the eastern end of the quarry the dip increases, according to the following observations: 8 degrees, 10 degrees, 18 degrees; the steepest dip is in the easternmost portion, where the abundance of corals indicates the neighborhood of the reef.

On the southwest, dark shaly limestones and bituminous shales overlie the limestone, and carry a rich coral and brachiopod fauna. (For analyses of the limestones of this quarry, see beyond.)

b. Richard Collins' Quarry:

This quarry, across the road from the previous one, shows the central reef with the flanking lime-sandstone strata dipping away from it. This quarry was formerly known as Phelps' lime kiln quarry, and Rominger, on page 43 of his report, mentions the central reef as a bubble-like protrusion. The relation of the fragmental strata and the reef mass is shown in the accompanying figure. The strata dip away from the reef in all directions. At first the angle is 28 degrees, then it falls to 14 degrees, then to 4 degrees, and finally to 2 degrees, the normal dip of the strata in the quarry. In the reef portion, the coral masses (heads of *Favosites alpen-*

ensis, various species of Stromatopora, and large heads of *Acervularia davidsoni*) are surrounded by the crystalline coral sand which filled in all the interstices between the coral heads as shown in the preceding figure, Fig. 2.

These interstitial limestone masses in the reef are generally made up of coarse fragments in which large crinoid joints predominate. Brachiopods and Bryozoa also occur here, for this was a favorite habitat of these animals. These interstitial masses are often re-crystallized, and crystals of dogtooth spar are often abundant.

The coral heads are generally of large size. Sometimes they are overturned, but most of them appear to lie in their normal position. In some places the crystalline coral sand forms most of the rock exposed, the large coral heads being scattered through the sand. This latter shows no stratification, which is found only on the flanks of the reef and beyond it. The sand in the cavities of the reef is generally much coarser than that on its flanks or farther away, a feature indicating normal sedimentation.

In places at some distance from the center of the reef the rock consists of an organic breccia, made of brachiopods, bryozoa, and the small branching corals plentifully interspersed with crinoid joints.

Away from the reef the limestone is bedded, wholly of fragmental origin, and made up directly of comminuted coral and crinoid remains. The stem joints of the latter stand out in relief on the weathered surfaces. Crinoid heads (Dolatocrinus) and small corals (Favosites, etc.) are found in the limestone, but such fossils are generally most abundant in the somewhat shaly films which separate the successive limestone strata.

The origin of these limestone masses and the accompanying beds of stratified limestone may be explained as follows:

In the Devonic sea of this region, the luxuriant growth of corals and other lime-secreting organisms produced isolated reefs, which rose to within the sphere of wave activity. Being subject to the continued attack of the waves, these reefs were destroyed wherever the vitality of the polyps was insufficient to resist the wave attack. Wherever exposed, the dead coral rock was ground into a coral sand, this being accomplished in part by the direct activity of the waves, in part by the aid of tools chiefly in the form of loose blocks which were rolled about, and served to grind up the coral rock, and in part by the many reef-destroying organisms, which in every reef are actively breaking up the dead coral masses. The resulting coral sand was carried away by the waves and currents and deposited on the flanks of the reefs, and in the quieter water beyond.

Stratification is well marked in such a fragmental limestone, or lime-sandstone, and it not infrequently happens that cross-bedding structure, ripplemarks, and other shallow water characteristics are shown in such a limestone. In fact, we may consider that there is no essential difference in structure between such lime-sandstones and ordinary quartz-sandstones, the mineralogical character of the component grains being the only distinction. In such a lime-sandstone fossils need not be abundant, in fact we could understand their total absence. Near the growing reef, which is the source of the coral sand, the minor reef organisms may be

expected to occur, but their number would decrease in proportion as we pass away from the reef. In the immediate vicinity of the reef, an interlocking of the organically and the mechanically formed limestones occurs, for at times the coral sand encroaches upon the reef, and again the reef organisms extend outward, growing on the foundation of sedimentary coral sand. This inter-locking of the two types of limestone is well shown in the quarries opened in the reefs in question, and on either side the stratified limestone, consisting wholly of consolidated coral sand, is seen dipping away from the reef. This stratified limestone is strikingly barren of organic remains; only a few brachiopods or small corals are found at intervals. In texture it is very uniform, and in composition very pure, yielding from 96 per cent to 99 per cent $CaCO_3$. (See analyses given beyond and under Loc. 9.)

The purity of these limestones is readily accounted for when we remember that the reef-building organisms flourish only in water free from terrigenous matter. Since the stratified limestone beds which always accompany the reef are derived from the organically formed limestone, and since there is an absence of terrigenous matter within the area of their deposition, it follows that these limestones must be very pure, within a radius of some magnitude from the central coral reef, the source of supply of the lime sand. It furthermore follows that the thickness of the coral reef, and the thickness of the flanking fragmental limestones, may agree and that beds of great thickness may accumulate, depending on the length of time during which the reef remains in an actively growing condition.

It thus appears that the reefs are the most trustworthy guides to the purity of the limestones. Close to the reefs from which they were formed, these limestones will generally be free from foreign material, while this may increase in amount progressively with the distance from the reef.

Loc. 1a. The rock exposed here shows essentially the same characteristics as that of the preceding two localities. *Favosites* appear to be the most common fossil. Other fossils are *Atrypa reticularis, Spirifer granulosus, Zaphrentis* sp., and several species of *Stropheodonta.*

Loc. 1b. The limestone has here less the character of a reef, but appears to have accumulated in the immediate neighborhood of a reef. It is highly fossiliferous, Favosites and Stromatopora being very common, though apparently not forming very large masses as in the reef portions of the preceding localities. Stropheodonta is a well-represented genus, though the species are generally small. *Gypidula romingeri* and *Atrypa reticularis* are among the other common brachiopods.

The limestone of the quarries is exposed in the fields at numerous localities north and east of the prospecting holes. Many small prospecting holes have been opened in it, but no extensive quarrying operations are carried on except in the two quarries mentioned and in that of the cement company.

To the south and southwest the limestone of Loc. 1 is overlain by a blue clay, which is exposed in a test well on Dock street, where it is six or seven feet thick. This clay will be mentioned again below.

The following analysis of the limestone of Collins' quarry was furnished by Mr. S. H. Ludlow, chemist of the Alpena Portland Cement Company, under No. 23:

SiO_2	.62
Al_2O_3	.60
Fe_2O_3	.33
$CaCO_3$	97.39
$MgCO_3$	1.09
	100.03

The following analyses of the rocks of Loc. 1 and of the limestones of the lower series were made for the Survey by Mr. F. Brady, chief chemist of the Illinois Steel Company from samples Mr. Grabau collected, received July 27, 1901:[18]

Marked.	Silica.	Ferric oxide.	Alumina.	Calcium carbonate.	Magnesia carb.	Sulphur.	Phos.
1. Alpena Loc. 1	.42	.19	.45	98.04	.88	.014	.007
2. " " 1	.24	.16	.26	98.88	.45	.006	.003
3. " " 1	.32	.29	.33	94.83	4.20	.020	.012
4. " " 1	1.18	.31	1.79	95.29	1.33	.089	.017
5. " " 1	.24	.16	.32	98.84	.43	.007	.004
6. N. of Alpena, Loc. 2	4.62	.45	1.15	92.38	1.36	.029	.013
7. N. of Long Lake, Loc. 5	4.54	.50	1.36	91.82	1.67	.084	.031
8. Cement Quarry, Loc. 9	.70	.30	.76	96.90	1.30	.022	.020
9. " " " 9	.38	.19	.21	98.60	.52	.009	.004

[18] The following partial analyses were made for A. C. Lane.

1. From the Collins quarry: Limestone dipping away from a reef on which the kiln stands. The upper layer is rather blue and shaly, with *Phacops rana, A. reticularis, S. mucronatus*, etc. The analysis of the sample made by A. N. Clark:

$CaCO_3$	95.40
$MgCO_3$	1.76
Insoluble, SiO_2, etc	1.10
Organic and loss	1.74
	100.00

2. From the same neighborhood samples yielded the Dow Chemical Co.

	1	2	3
SiO_2	3.18	4.01	2.51
Iron and alumina	1.43	2.20	1.81

DESCRIPTIONS OF SAMPLES ANALYZED.

No. 1. Fragmental semi-porous limestone consisting of ground-up organic remains. Loc. 1, Collins quarry, Alpena.
No. 2. Fragment of unweathered and unfilled Acervularia. Fox's quarry, Loc. 1, Alpena.
No. 3. Compact light crystalline limestone, forming the lower beds in Fox's quarry, Loc. 1, Alpena.
No. 4. Dark crystalline limestone forming the upper beds in Fox's quarry, Loc. 1, Alpena.
No. 5. Fragment of Stromatopora, unaltered. Fox's quarry, Loc. 1, Alpena.
No. 6. Porous fragmental limestone from roadside about a mile north of Alpena at Loc. 2. Somewhat oxidized. Surface specimen.
No. 7. Compact gray limestone from Loc. 5, Alpena, just overlying the Stropheodonta shales. Long lake.
No. 8. Compact lime sandstone from quarry opposite cement works, Loc. 9 (Alpena Cement Co.'s quarry).
No. 9. Fragment of Favosites with cavities filled by infiltration. Cement quarry, Loc. 9, Alpena.

Nos. 2, 5 and 9 represent the chief corals which make up the coral reef in the Alpena limestone, and from the destruction of which the flanking beds of limestone or fragmental limestone were formed. It will be observed that they are very low in silica, and approach 99 per cent of $CaCO_3$. They are furthermore low in $MgCO_3$, showing that these corals are practically pure lime structures. The silica is probably a secondary introduction, being highest in the Favosites, where the intertabular spaces were filled by infiltration.

The only other sample high in lime is No. 1, which represents the comminuted coral and shells which made up the old reef. The sample came from the flanks of the old reef and shows the purity of the rock derived from the reef.

The light colored lime-sandstone, forming the chief fragmental beds, resting upon the old reef exposed in Fox's quarry (No. 3), is lower in its percentage of lime than the dark limestone overlying it (No. 4). This is due to the high percentage of magnesium carbonate (4.20), which is most likely of later origin, having replaced the original calcium carbonate. The percentage of silica and alumina is not much higher in this rock than in the corals from which it was derived, and a tenth of a per cent lower than in the fragmental lime rock from the reef in Collins' quarry (No. 1), which is high in lime and comparatively low in magnesia. The upper beds in this region, as represented by the analysis of sample 4, are comparatively high in silica and alumina owing to the presence of diminutive clay particles, which give this rock its relatively dark tint. These beds grade upward into calcareous shales.

Nos. 6 and 7 are high in silica, not so much from the presence of clay, for there is a smaller amount of alumina than occurs in sample 4, but rather from a certain amount of silicification of the contained organic remains. This has not been carried very far, however, the percentage of silica not rising much above 4.5.

The analysis of the limestone from the cement quarry (No. 8) represents the average of this rock in its percentage of lime, though 98 per cent, and even 99 per cent and over, have been recorded. The presence of a considerable per cent of $MgCO_3$ in sample 8 accounts in part for its lower per cent of $CaCO_3$.

The following analyses were given in the last annual report:

LIMESTONES FROM QUARRIES OF ALPENA PORTLAND CEMENT COMPANY.

	1.	2.	3.	4.	5.	6.	7.	8.	9.
Calcium carbonate	95.91	89.10	98.37	98.03	96.35	96.50	96.92	98.14	98.03
Magnesia carbonate	3.63	8.67	.92	1.36	.94	1.26	.98	.98	1.05
Silica	.36	1.77	.33	.38	1.38	1.64	1.46	.42	.68
Iron oxide } Alumina }	.13	.35	.18	.19	1.21	.27	.54	.18	.26
Total	100.03	99.89	99.80	99.96	99.98	99.67	99.90	99.72	100.04

No. 1. Quarry C. Shell to be removed in stripping. One to two feet thick.
No. 2. Quarry C. Top strata. Two feet thick.
No. 3. Quarry C. Second strata. Two feet thick.
No. 4. Quarry C. Third strata. Four feet thick.
No. 5. Quarry C. Fourth strata. Two feet thick.
No. 6. Quarry F. First strata. Two feet thick.
No. 7. Quarry F. Second strata. One foot thick.
No. 8. Quarry F. Third strata. Two feet thick.
No. 9. Quarry F. Fourth strata. Floor of quarry.
All samples show traces of sulphates and phosphates.

Chemist, F. M. HALDEMAN.

Alpena, Mich., Feb. 12, 1900.

The analysis of a limestone near Rogers City, given Mr. Lane by J. G. Dean, may be inserted here for comparison:

Calcium carbonate	96.34
Magnesium carbonate	0.45
Alumina and iron	0.20
Silica	0.62
Sulphates	traces
Organic matter	0.09
Difference	0.30
	100.00

A yellow clay shale near by (weathered Bell shale?) gave:

Silica	66.39
Alumina	13.60
Iron oxide	5.87
Lime	.99
Magnesia	.50
Sulphuric anhydride	1.00
Organic matter and water	10.32
Difference	1.33
	100.00

A specimen of the Alpena stone gave W. M. Courtis, M. E.:

Calcium carbonate	95.231
Magnesium carbonate	0.946
Ferric oxide	0.536
Alumina	0.150
Silica { insoluble 1.205 soluble 0.113 }	1.318
Organic matter	1.510
Water	0.300
Phosphoric acid	traces
Sulphuric acid	Slight traces
Chlorine	Slight traces
Alkalies	traces
	100.00 per cent.

The following analyses of limestone from the quaries of M. J. Griffin in the Alpena limestone at Bolton[14] which were made by E. J. Schneider, chemist, yielded, calculated from limestone:

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
SiO_2	1.81	.16	1.67	1.39	2.85	1.39
Fe_2O_3 & Al_2O_3	1.54	1.32	1.42	2.56	1.10	1.49
CaO	93.44	95.89	96.96	94.48	93.51	95.53
MgO	2.99	.53	.49	.14	1.69	1.81
Loss	99.58	97.90	100.54	98.57	99.15	100.22
Corresponding Limestone.						
SiO_2	1.2	.2	1.0	.8	1.54	1.8
$(Fe_2 Al_2)O_3$	.9	.8	.8	1.5	.63	.9
$CaCO_3$	94.4	95.5	97.6	97.5	95.7	97.9
$MgCO_3$	3.5	.6	.6	.2	2.13	3.20
	100.00	100.00	100.00	100.00	100.00	100.00

Location of sample taken.
No. 1. Railroad cut on surface.
No. 2. First quarry on surface of subterranean passage.
No. 3. " " top layer 5 feet from surface.
No. 4. " " " " 8 " "
No. 5. New " " layer from surface to 3 feet down.
No. 6. Top layer on surface ¼ mile back from quarry.
Top layer at subterranean passage 8 feet in thickness, while that at new quarry is 5 feet.

The following analyses of the limestones of the cement quarry were furnished by Mr. S. H. Ludlow:

Sample No.	SiO_2.	Al_2O_3. and Fe_2O_3.	$CaCO_3$.	$MgCO_3$.
1	.32	.55	98.23	.98
4	*	.73	95.16	3.91
6	*	.34	98.62	1.04
22B	.....	.....	98.03	.....
22C	.....	.....	98.58	.....
24B	.....	.....	98.32	.....
25	.....	.....	99.19	.....

* Included in next column.

No. 4, the lowest in $CaCO_3$, is the richest in $MgCO_3$, containing nearly 4 per cent. Large areas here and there in the quarry are relatively rich in magnesia, and these do not effervesce with dilute HCl. In general the rocks here have a porous texture and are commonly more oxidized than the rest of the rock, sometimes having a deep ochre color.

No. 25 yielded the highest per cent of lime obtained in the quarry at that time.

No. 6 is a bluish coralline limestone of a flinty texture, and probably represents a part of the reef. No. 24b is known as sugar stone.

A sample taken at a depth of 32 feet in the well of the cement company,

[14] There is, however, at Bolton also a layer of dolomite with 56 per cent Ca CO_3.

and therefore representing the lower portion of the Alpena limestone, has given the following analysis:

SiO_2	.40
$CaCO_3$	97.16
Al_2O_3 and Fe_2O_3	1.00
$MgCO_3$	1.06
	99.62

This, therefore, compares well with the average of the limestones of this bed.

The following analyses of a recent large blast of coral limestone from the reef in the cement quarry was also furnished by Mr. Ludlow:

SiO_2	.21
Al_2O_3	.33
Fe_2O_3	.....
$CaCO_3$	99.33
$MgCO_3$	.21
	100.08

A later blast gave 99.63 per cent of $CaCO_3$.

An analysis of the limestone from some distance northeast of the cement works (Isaacson stone), and two feet from the surface, gave the following results:

$CaCO_3$	96.75
Al_2O_3 and Fe_2O_3	1.06
SiO_2	.79
MgO	.35
	98.95

The Portland cement made by the cement company from this rock gives the following results, from 26 to 27 per cent of the clay of Loc. 31 being added to the limestone:

SiO_2	20.26
Al_2O_3	8.62
Fe_2O_3	2.71
CaO	63.22
MgO	2.34
K_2O and Na_2O	1.34
SiO_2	.76
H_2O and CO_2	.75
	100.00

Loc. 2. About two miles north of Alpena, at Sta. 11 on the section line, a highly fossiliferous limestone is exposed along the roadside and in the adjoining farm lands. This rock consists mainly of the stems and joints of crinoids, and of various Bryozoa, among which the fenestelloids are the most common. In the exposed portions the fossils appear to form a loosely agglomerate mass, without the interstitial filling of calcareous sand. Brachiopods are very common, and the space between the valves is generally unfilled, except for subsequently infiltrated calcite. The brachidium of these brachiopods is generally well preserved, indicating a freedom from disturbances. *Gypidula romingeri* and *Atrypa reticularis* are both abundant. Stropheodonta cf. *S. demissa* and *S. nacrea* are also common. *Chonetes coronatus* is a conspicuous species, while *Spirifer mucronatus* and *S. granulosus* are among the other characteristics brachiopods.

Fenestella, Loculipora, and the other frondose Bryozoa are also well preserved, frequently still showing the original funnel-like form of the frond.

Crinoid stems and joints make up the greater portion of the mass. These are mostly enlarged, and changed to cleavable calcite. Dog-tooth spar is common in the cavities, which latter are very numerous, since all the remains are loosely joined, forming a porous or loose-textured rock.

No Favosites or other corals have been observed. The condition of preservation of these fossils is such as to point to quiet and rather deep water wherein they accumulated, in a depth apparently beyond that of wave activity. This limestone was therefore of great purity, since it consists wholly of the calcareous remains of organisms, but it has since been somewhat silicified as shown by No. 6, of Brady's analyses on page 179. The position of the limestone appears to be near the base of the middle Traverse limestone (stratum 2), but its characters are probably not traceable over a very large area.

Loc. 3. About a mile north of this outcrop, at Sta. 15, is another outcrop of limestone along the west line of Sec. 35. Here the limestone has again the coral-reef character, with Acervularia and Favosites predominating. This exposure belongs near the base of the limestone series. Besides the fossils mentioned, Zaphrentis, fenestelloids, *Atrypa reticularis* and crinoid stems may be mentioned.

Loc. 4. This is two-tenths of a mile north of the last locality, at Sta. 17a, along the east line of Sec. 27. The limestone here is similar to the preceding, and belongs to the same series. It contains numerous crinoid remains, and Stropheodonta is the commonest genus of brachiopods.

THE LOWER TRAVERSE SERIES.

a. Long lake shales and limestones:

These beds are a succession of thin-bedded limestones and shales, exposed both north and south of Long lake. This occupies a depression underlain by one of the prominent beds of blue clay shale occurring in this series.

Loc. 5. About a third of a mile north of Loc. 4, at Sta. 19, on the section line, is an outcrop of impure but highly fossiliferous limestone, which weathers to a yellowish-brown color, and leaves an earthy residuum. The reef corals are rare, but other types, such as Zaphrentis, Aulopora, and the like, are met with. Brachiopods are common and among these a robust

variety of *Atrypa reticularis* is the most abundant. Other common species are: *Spirifer mucronatus, Chonetes coronatus, Stropheodonta demissa, S. concava,* and *S. erratica* (?).

From the thin bedded character of this rock, it might well be mistaken for a shale in the drill record. At any rate, this rock underlies the crystalline limestone, and with the beds next below it probably forms the nine-foot stratum of "shale" (stratum No. 3) in the Churchill well record.

Loc. 6. Less than two-tenths of a mile to the north, at Sta. 20, is an outcrop of black shale, highly bituminous, and characterized by the extreme abundance of a small species of Stropheodonta. This is a species closely related to *S. plicata* of the Iowa Hamilton. The plications are angular near the beak, but become rounded and less pronounced toward the front. The exterior of the shell is striate, the interior pustulose. When worn, the shell appears punctate. A few fenestelloids occur, but other fossils are very rare.

Loc. 7. This is at Sta. 21, on the section line, something more than two-tenths of a mile north of the preceding locality. The rock is a dark-colored, somewhat shaly, fine-grained bituminous limestone, and lies just below the shales of Loc. 6. It is exposed at the base of a terrace, on the west side of the road, and fossils are very rare in the exposed portion.

Loc. 26. Thunder Bay Island. This island is the easternmost point of land north of Thunder Bay. It consists of flat ledges of limestone rising but slightly above the water level. During high storms the water sweeps the ledges bare. The limestone is composed of crinoid fragments, brachiopods, and corals, with a predominance of fine coral sand. Stromatopora is the most abundant fossil, large heads from one to two feet in diameter being very frequent, and some even up to five feet in diameter having been noted. Wherever they occur, the surface presents a hummocky appearance, the Stromatopora heads rising in dome-like masses, over which the strata arch. On the eastern end of the island the limestone layers are separated by shaly beds often several inches in thickness. These shaly beds are highly bituminous, black, easily soiling the fingers, and with a petroleum odor. The surface of the layers is covered by black, glistening, carbonaceous deposits. The limestone is dark and generally of a shaly character. Favosites of several species and Acervularia are common, though the latter has not been seen in large heads. The shale often has the appearance of being sun cracked. The black shale contains brachiopods (*Stropheodonta costata,* Owen (?) and others) and branching Favosites. It varies in thickness up to half a foot and contains numerous pyrite concretions, which on oxidizing stain the rock and leave cavities.

In the limestone and associate shales the following fossils have been found, among others, in the beds of Thunder Bay Island: Stromatopora, *Acervularia davidsoni,* Proetus sp., *Spirifer mucronatus, Atrypa reticularis, Stropheodonta erratica, S.* cf. *costata, S. nacrea, Chonetes,* cf. *coronatus, Meristella* cf. *nasuta, Gypidula romingeri.* Rominger also mentions *Proetus crassimarginatus, Phacops bufo* (?*rana*), Gomphoceras, Orthoceras, *Eunella lincklaeni,* and *Spirifer consobrinus* as other common species.

These limestones and shales apparently represent the beds found 20 to 40 feet below the Alpena limestone in the cement company's well (No.2). Here black shales are common. The black shales of Loc. 6 are doubtless

the same as those of Thunder Bay Island, though in these latter the small angularly plicated Stropheodonta appears to be less abundant.

Rock of the same type and carrying the same fossils as on Thunder Bay Island is found on Sugar Island, but the ledges are mostly submerged.

Along the eastern shore of Thunder Bay Island the ledges extend out under the water for some distance, submerged from two to three feet. Then they suddenly break off and a submerged cliff carries the lake bottom down six fathoms. This cliff is probably the wall of a sink hole similar to that found at the head of Misery bay.

Loc. 27. This is an exposure along the road side (section line) forming the western border of the southwestern quarter of the northwestern quarter of Sec. 25, R. 8 E., T. 32 N. Here the road is crossed by a terrace of compact gray limestone containing Acervularia, Favosites, Stromatopora, and occasionally crinoid joints. Lower down, some beds are filled with a robust variety of *Athyris fultonensis* (?), which often becomes large, and then has the aspect of a Seminula, or of *Meristella nasuta* without the anterior strong protrusion. *Crytina umbonata alpenensis* is extremely abundant, as is also *Stropheodonta* cf. *costata.* Other common species are *Productella spinulicosta* and *Spirifer mucronatus* with characteristic features; also, less common, *Stropheodonta nacrea, Spirorbis,* etc. These beds appear to lie above those of Loc. 8 *et seq.,* as is indicated by the strongly plicated *Stropheodonta* cf. *costata,* which scarcely occurs in or below the beds of Loc. 8, also abundant in the lower beds.

Loc. 28. This is another outcrop a quarter of a mile or less northeast of the preceding locality. On the road between Secs. 24 and 25, near the western end of the sections, are exposures of coralline limestone that show *Acervularia davidsoni, Favosites alpenensis, Atrypa reticularis,* Cyathophyllum, etc. This may be the continuation of the beds exposed in Loc. 8. (See below.)

Loc. 8. This is at Sta. 22, on the section line near the forks of the road south of Long lake. The rock is thin-bedded, gray, weathering to buff, and highly fossiliferous. Favosites and Acervularia occur, but not in very large masses. *Atrypa reticularis,* represented by an extremely convex variety, is the most abundant brachiopod. Several species of Stropheodonta occur, among which a variety of *S. demissa,* and *S. erratica,* and *S. inequistriata* should be mentioned. *Cyrtina hamiltonensis* also occurs. These limestones are probably a part of the stratum 4 series of the Churchill well.

Loc. 32. The same beds in the second season's fieldwork were designated Loc. 32. In addition to the species mentioned, the following should be noted among others: *Spirifer mucronatus, S. audaculus, Productella spinulicosta, Orthis (Schizophoria) propinqua,* a large species, rather common, *Gypidula romingeri, Athyris fultonensis,* Favosites, Aulopora, *Acervularia davidsoni,* and numerous cup corals, among which Zaphrentis, Heliophyllum, and Cyathophyllum predominate. Bryozoa are also common.

Loc. 33. This is along the Long lake road, half a mile or more northwest of the point where the Bell road branches off from the Long lake road. The rock here is a dark, easily split lime shale, having very uneven surfaces, and weathering into red clay. These beds are but slightly below those of Loc. 8, the two localities being nearly along the strike of

the beds. They are rich in crinoid joints and corals are extremely abundant. These are mainly silicified and comprise *Acervularia davidsoni,* several species of Zaphrentis, Cyathophyllum, and others. *Atrypa reticularis* is common and of the robust type found in the beds above. With it occurs the large *Orthis propinqua, Gypidula romingeri, Spirifer granulosus, Sp. mucronatus, Sp.* cf. *varicosus,* and several species of Stropheodonta, including *S. erratica, S. demissa,* and *S. nacrea,* the last three being rare; also *Productella* cf. *productoides, Crytina hamiltonensis, Athyris fultonensis, Gypidula romingeri, Pentamerella dubia, Phacops rana, etc.* Bryozoa are also common.

Loc. 33a. A quarter of a mile southeast of Loc. 33, or halfway between Locs. 32 and 33, and in beds of about the same level, the following species have been found: *Atrypa reticularis, Spirifer mucronatus, Sp. granulosus, Sp.* cf. *varicosus, Athyris fultonensis, Gypidula romingeri, Orthis propinqua* of large size, *Productella spinulicosta, Cyrtina hamiltonensis, Stropheodonta erratica,* and, more rarely, *S.* cf. *costata* and *Crania hamiltoniae.* Of corals, *Acervularia davidsoni,* Zaphrentis, and Favosites occur.

Loc. 34. This is on Long lake road, north of the preceding localities, and on the slope of the terrace leading down to the lake. The chief fossils found here are Acervularia, Craspedophyllum, and Zaphrentis, the rock consisting mostly of coral masses. *Heliophyllum coalitum* also occurs, as well as Favosites. *Atrypa reticularis* is less robust and common in these beds, which are below those of the preceding localities.

Loc. 10. This exposure is at Sta. 24, where Hell creek, the outlet of Long lake, cascades over some limestone ledges. This locality is off the section, and the rock here exposed appears to be the correlative of the limestone series No. 6 of the Churchill well. Acervularia and Favosites occur here, and with these *Spirifer granulosus, Sp. mucronatus, Atrypa reticularis,* and *Orthis* cf. *propinqua.* This same rock probably crops out close to the lake.

Loc. 30. This is on top of the terrace fronting Hell creek, and on the line of the railroad of the Alpena Portland Cement Company, about two miles south of the clay pits. It is the continuation of the terrace fronting Long lake, and along the strike of the beds of the terrace. The beds of this locality are therefore of the same horizon as those near Long lake. Outcrops of this rock occur all along the front of the terrace and over the top, and weathered-out specimens may be picked up everywhere in the fields. The fossils are generally silicified, especially the corals. *Acervularia davidsoni* is very common in places, occurring in thin, explanate heads. Stromatopora and other corals found at Long lake occur likewise. Among the characteristics brachiopods are: *Orthis propinqua,* large form; *Gypidula romingeri; Atrypa reticularis,* very robust and extremely abundant; *Athyris fultonensis; Cyrtina hamiltonensis; Spirifer mucronatus,* abundant and characteristic; *Sp. granulosus; Stropheodonta nacrea; Str. sp.,* and *Productella spinulicosta.* The faunal correspondence is obvious.

Loc. 20. Misery bay. At the head of the inlet known as Misery bay or Little Thunder bay, a large sink hole, known as "the bottomless hole," has formed, from the bottom of which strong springs arise. The western wall of this sink hole remains as a vertical cliff composed of thin-bedded lime-

stones separated by shale partings. Large masses are continually separating along joint planes and falling into the bay. The beds are strongly iron-stained, and rich in brachiopods, among which the robust *Atrypa reticularis* of the Long lake localities predominates. These limestones are found on the surface for a considerable distance eastward of the bay. Their equivalency to the beds of localities 32 and 33 is probable.

Loc. 29. Wiesey's Well. A short distance northeast of the terrace described under Loc. 30, and between it and Hell creek, a well was sunk on the farm of Mr. Wiesey, which revealed twenty feet of bluish clay with some calcareous beds intercalated, the whole underlying the calcareous beds of Loc. 30. This is the shale which in part underlies Long lake, and probably is bed No. 7 of the Churchill well record. The calcareous beds are very fossiliferous, and especially rich in typical specimens of *Spirifer mucronatus.* Other fossils are *Stropheodonta demissa,* typical form, *Stropheodonta perplana; Chonetes coronatus; Chonetes sp.; Athyris fultonensis;* Modiomorpha, etc.

An analysis of the shale from Mr. Wiesey's well was furnished by Mr. Monaghan, as follows:

SiO_2	55.68
Al_2O_3 and Fe_2O_3	20.68
CaO	9.69
Mg O	2.35
Alkalies	3.60

Locs. 11-13. These are small outcrops of limestone along the roadside at Stas. 26, 27 and 29 respectively. They appear to belong to the limestone bed (No. 8 of the Churchill record) which underlies the blue shale of Long lake (7), and contain Acervularia, Gypidula, and other fossils characteristic of the massive limestones.

These beds are again seen in the high ridge of limestone north of Loc. 31. This ridge extends northwest and southeast, and can be traced almost to the shore, opposite Middle Island. Its average height is about 35 feet above the plain of the clay pits (Loc. 31).

Loc. 31. Clay Pits. The clay pits of the Alpena Portland Cement Company are situated in the N. E. ¼ of S. E. ¼, Sec. 18, T. 32 N., R. 9 E. They are begun on a stripped level, about twenty feet above the surface of Lake Huron.

The clay at present mined represents the upper beds of the series, about six feet in depth, which are thoroughly delithified and very homogeneous. Fossils are rare in this mass, but typical *Spirifer mucronatus, Stropheodonta demissa,* and *Phacops rana* are found in it, besides other species. At the base of this mass in a compact bluish clay shale, with calcareous layers full of typical *Spirifer mucronatus, Chonetes* cf. *deflecta, Stropheodonta demissa, Athyris fultonensis, Diclasma romingeri,* and other species. Lower down (31a), and exposed in the drain ditch, are calcareous beds containing *Cyrtina hamiltonensis, Stropheodonta demissa, Athyris fultonensis, Diclasma romingeri, Atrypa reticularis, Meristella* cf. *meta, Orthis iowensis* cf. *propinqua, Spirifer granulosus,* and *Sp. mucronatus,* besides Favosites, Zaphrentis, Cystiphyllum, and *Acervularia davidsoni.*

Loc. 31c. Overlying the clay beds is a thin-bedded limestone, rich in *Atrypa reticularis, Chonetes coronatus, Spirifer mucronatus, Sp. auda-*

culus, Sp. granulosus, Stropheodonta nacrea, Str. demissa, variety, *Str. erratica,* and numerous corals, including *Acervularia davidsoni, Cystiphyllum vesiculosum,* Zaphrentis, etc.

Loc. 31d. From a test hole in the woods, the following species have been obtained from the top beds of the clay, and the calcareous beds immediately above: *Cladopora alpenensis, Aulopora serpens, Cyathophyllum houghtoni, Zaphrentis* cf. *nodulosa,* Favosites, *Stropheodonta demissa, Stropheodonta* sp., *Spirifer mucronatus, Atrypa reticularis,* Chonetes, etc.

The following analysis of the upper clays (those used in the cement works) was furnished by Mr. Ludlow. (See also analysis in Ries's report on clays and shales, Vol. VIII, Part I, page 48.):

SiO_2	57.96
Al_2O_3	20.44
Fe_2O_3	3.03
$Ca\ CO_3$	9.12
CaO	.28
$MgCO_3$	5.02
SO_3	.72
	96.57
Alkalies	3.43
	100.00

The following analysis of the calcareous beds below the clay of the clay pit was furnished by Mr. Monaghan:

SiO_2	28.38
$Ca\ CO_3$	59.00
$MgCO_3$	1.93
Fe_2O_3	1.59
Al_2O_3	7.23
	98.13

Loc. 14. This is at Sta. 33, half way between Long and Grand lakes. The best outcrops are along the roadside and on the farm of Mr. Rabiteau. The rock is thin-bedded and extremely fossiliferous, the fossils weathering out in relief. The limestone is not very pure, an earthy residuum remaining on the solution of the lime. This is by far the most fossiliferous of the lower series of beds in the region, a large number of species having been obtained from the outcrops of this rock. Brachiopods predominate, with the large and robust *Atrypa reticularis* at the head. *Gypidula romingeri* Hall and Clarke is also extremely abundant, while the Stropheodontas and Spirifers are common, and represented by all the common and some rare species. Chonetes, Productella, and other characteristic Hamiltonian brachiopods occur abundantly. Among corals the smaller types predominate, i. e., Aulopora, Ceratopora, etc. In the lower beds, however, the reef-building types occur, notably Acervularia. Stromatoporoids are also, though more rarely, met with.

Loc. 18. This is on the farm land north of the county line and east of the line of the section. The outcrop is in line with those of Loc. 14, and of the same type, containing also the same species of fossils.

Loc. 35. This is an exposure of the upper beds along the strike of the beds from Loc. 14, in the southwestern quarter of Sec. 36, and near the sink holes of Loc. 19. The fossils were collected under the root of an upturned tree. Zaphrentis and Ceratopora are most abundant. The following is a partial list: *Heliophyllum juvene,* Cyathophyllum, Zaphrentis, *Acervularia davidsoni,* Favosites, Ceratopora, *Atrypa reticularis, Athyris fultonensis, Stropheodonta erratica, S. demissa, Athyris spiriferoides* (?), *Pentamerella dubia* (?), *Cyrtina umbonata alpenensis,* etc. These beds may be considered identical with those found on Rabiteau's farm (Loc. 14).

Loc. 37. Grand lake ledges. These ledges are exposed on the southwest shore of Grand lake, opposite Kaufman's hotel. The cliff rises perhaps 40 feet above the level of the lake; the lower half is obscured by a talus slope. The beds are the northwest continuation of the lowest beds, seen near the base of the terrace north of Loc. 14. The upper layers are full of a species of Ceratopora, which in places constitutes almost the only fossil seen, with the exception of crinoid joints and stems. Below this are about 10 feet of a compact, fine-grained limestone, with occasional large heads of Acervularia. Below this the beds become somewhat shaly and contain large specimens of Zaphrentis, Cyathophyllum, etc.

These ledges are again exposed in T. 32 N., R. 9 E., Sec. 6, directly west of Middle Island. Here they form a chain of bluffs 16 feet high, which commence about half a mile from the shore. "Nearly the entire rock is made up of specimens of Stromatopora mingled with Favosites, *Cyathophyllum profundum, Diphyphyllum archiaci,* and other corals, which by exposure easily become disintegrated" (Rominger, loc. cit. p. 50). I have not seen this exposure, but it is well described by Rominger and its relation to the Grand lake ledges appears clear.

Loc. 19. Sink holes. The sink holes are situated in the southwest quarter of Sec. 36, T. 33 N., R. 8 E. There are at least a dozen of them extending in a northwest and southeast line through Sec. 36 and into Sec. 35. They are generally at the bottom of a ravine or longitudinal depression. The great "bottomless" sink has vertical sides of overhanging cliffs on all sides, and has a depth to the water surface of about 50 feet (estimated). The water in the bottom has a similar or greater depth. The upper 20 feet or more of the wall consist of limestones, the basal beds of the Long lake series, which form a vertical cliff. Below these are the blue Bell shales, which weather back, leaving the limestone cliffs overhangnig.

In the majority of sink holes the greater part of the cliff is talus covered. Where the upper beds are exposed they are seen to be fine grained, very homogeneous limestones, with a smooth, somewhat conchoidal fracture, and spotted by scattered masses of calcite. These are granular, and appear to have replaced minute organisms. The rock is singularly barren of organic remains; only occasionally a coral or fragment of a brachiopod is found. It is for the most part composed of a fine lime mud, in which even stratification is not well marked. The rock is heavy bedded and broken by frost into large cubical blocks. The thickness of the stratum is about 10 or 12 feet.

Below this are six feet or more of shales, frequently bituminous, and covered with alum efflorescence. They contain numerous small branching Favosites and a few other fossils. Below this, limestones occur again, which, together with the bituminous beds and the compact limestone on top form the upper part of the beds seen in the walls of the great sink hole.

B.—THE BELL SHALES.

These shales are for the most part inaccessible, since they are either deeply eroded or covered by drift deposits along their line of outcrop. From the well records we know their thickness to be about 80 feet, which thickness is pretty nearly constant over the northern part of the state. For some years the clay was dug north of Bell and manufactured into bricks. The works have, however, been abandoned for many years and the pits are full of water. Grand lake is undoubtedly underlain by these shales, or carved out of them, but no exposures are found. The only place where the shales may actually be seen is in the cliff of the great sink hole before mentioned, of which they constitute the lower portion. They are, however, quite inaccessible. In color they are blue, like those of the Cement company's clay pit, and it is very probable that they contain the typical lower Hamilton faunas. The black Marcellus shales are absent in this region, and hence we must not expect to find a typical Marcellus fauna. Rominger (p. 50) mentions an exposure of blue shales at the base of the bluff in Sec. 6, T. 32 N., R. 8 E., and gives a long list of typical Hamilton fossils from these. These beds apparently represent the upper portion of the Bell shale.

THE DUNDEE LIMESTONE.

This limestone, which underlies the Bell shale, was struck in the Churchill well at a depth of 444 feet. Its occurrence on Middle Island is noted by Rominger, who, however, refers it to the basal Hamilton. The following localities have been examined:

Loc. 15. This is along the shore of Burnham bay, southwest of Presque Isle. No outcrops are found here, but the beach is composed of rounded and subangular dark to light gray limestone pebbles. Chert is a common constituent of this rock, which probably belongs to this formation (representing the Corniferous limestone).

Loc. 16. This is in front of Presque Isle light, along the shore of Lake Huron. A dark, somewhat shaly, apparently non-fossiliferous limestone crops out at the water's edge. This undoubtedly is the lower Dundee limestone (stratum 19), which probably forms the shore for a considerable portion of the county.

Loc. 17. This is on the mainland, north of Presque Isle. The rock, though locally disturbed, chiefly by shore ice, is undoubtedly in place, and represents the stratum overlying that which crops out in front of Presque Isle light. The rock is a very compact and uniform grained limestone, of a drab color, and sparingly fossiliferous. Almost the only fossil found in it was a large and rather smooth Paracyclas *(P. elliptica)*.

Loc. 36. False Presque Isle. Along the outer shore of this peninsula a compact limestone is exposed in low, flat slabs at the water's edge. Behind this are high beaches of limestone pebbles. The rock is sparingly

fossiliferous, and the following species have so far been recognized among those collected: *Atrypa reticularis, Stropheodonta* cf. *demissa,* Zaphrentis, Cystiphyllum, *Euomphalus* cf. *decewi, Euomphalus* cf. *clymenioides, Paracyclas elliptica.* The last three species mentioned are characteristic of the Onondaga formation of New York and Ontario. They may be regarded as indicative of the Onondaga (Dundee) age of the beds in question. The same species are recorded by Rominger from Middle Island, and again from Crawford's marble quarry along the north shore.

(THUNDER BAY SERIES) TRAVERSE UPPER SHALES AND LIMESTONES.

There are fewer and less satisfactory exposures of the Thunder Bay or Upper Traverse series than of the lower series, owing chiefly to the less calcareous character of the strata of the upper series, which allowed deeper erosion. Fewer localities have been examined so far, hence the present report on the upper series will be less complete. The following localities are arranged in the ascending order of the strata:

Loc. 1c. Dock street clay. This is the remnant of a clay or shale bed overlying the limestone of Loc. 1. In a test well on Dock street it was found to be about six feet deep. The following analysis of this clay was furnished by Mr. Monaghan, and represents a sample taken five feet below the surface:

ANALYSIS OF DOCK STREET CLAY.

SiO_2	55.80	(or calculating	SiO_2	55.80
Fe_2O_3	5.11	Mg and Ca as	Fe_2O_3	5.11
Al_2O_3	20.93	Carbonates)	Al_2O_3	20.93
CaO	1.98		$CaCO_3$	3.53
MgO	1.23		$MgCO_3$	2.57
Alkalies	5.55		Alkalies	5.55
Loss by ignition	7.78		Loss by ignition	7.78
Total	98.38		Total	101.27

Overlying this clay shale is a thin bed of limestone from two to three inches in thickness, of which fragments are scattered about on the fields southwest of the quarries. This limestone in places is filled with a small variety of *Cyrtina umbonata,* which resembles in most respects the typical form of the species from Iowa.[15] It is smaller, less robust, and with the beak less arched than is the case in the variety *alpenensis,* which is the most characteristic form of the higher strata.

Loc. 21. Fletcher dam. This locality, formerly known as Broadwell's saw mill and mentioned by Rominger under that name (loc. cit. p. 44), is on Thunder Bay river, in Sec. 7, R. 8 E., T. 31 N. At the Fletcher pulp and paper mill, a reef of the type found in Loc. 1, but less extensive, appears in the river bottom, and formerly caused a fall of several feet. The dam was built over this reef, and thus the strata at this point are not accessible. Large heads of Favosites and large specimens of Cystiphyllum occur among the debris at the base of the fall. On the right bank below the dam, the strata dip about eight degrees down stream. On the left bank of the race below the mill, about six feet of rock are exposed. The upper half of this is an earthy, gray, thin-bedded fossiliferous limestone, with beds perhaps three-fourths feet thick, and less. The

[15] See Pal. Iowa, pl. 5, fig. 2, 1858.

lower half is a bluish gray, calcareous shale, with a sandy feel, and the appearance of a natural cement rock. This is full of what appear to be sun-cracks, and only occasionally contains fossils. *Atrypa reticularis, Spirifer granulosus, S. mucronatus,* and Ceratopora have been observed in it, besides fenestelloids. This shale is exposed for about 20 feet down stream, when the dip carries it below the water. The dip at the upper end of the race is five degrees east of south, which abnormal direction and large angle is probably due to the buried reef.

In the race below the mill the lower strata have been uncovered, and the fragments thrown upon the bank have weathered and readily yield their fossils. This rock has the appearance of a limestone breccia in which the spaces between the limestone fragments are filled by masses of bluish gray clay. Both clay and limestone effervesce freely with dilute hydrochloric acid. It is essentially an old reef of Bryozoa and branching corals, among which *Craspedophyllum archiaci* and a small species of Ceratopora (?) predominate. Branching species of Favosites, and the large spreading masses of *F. placenta* and large heads of *Favosites alpenensis,* var *billingsi,* are common, and with them occur *Strombodes alpenensis, Acervularia davidsoni,* and occasionally *Cystiphyllum vesiculosum.* Bryozoa of various types are abundant, but brachiopods are comparatively rare. Among those found are *Spirifer asper, Sp. audaculus, Cyclorhina nobilis,* and *Atrypa reticularis.* Crinoid stems are abundant, and heads also occur. Those noted are *Dolatocrinus triadactylus* and *Dolatocrinus sp.*

The following analysis of the blue shale at Fletcher's dam (second bed from the top) was furnished by Mr. Monaghan:

SiO_2	21.54
CaO	37.89
MgO	1.26
Al_2O_3	4.58
FeO	2.37

Loc. 24. Boom Company's dam. This locality is on Thunder Bay river, seven miles above Alpena and two miles or more above the preceding locality. (Sec. 2, R. 7 E., T. 31 N.) The mill site was formerly known as Trowbridge's mill, and is mentioned under that name by Rominger (loc. cit. p. 44). Along the left bank of the stream the shales are exposed in a cliff about 15 feet high. The lowest beds are bluish sandy lime shales, breaking irregularly and having a sub-concretionary character. They weather brown, and leave much earthy residuum. Fossils are rare. In appearance these shales resemble somewhat the lower exposed beds of the Fletcher dam section, and both are not unlike the blue beds of the Warner brickyard (Loc. 25). Spirifer and small corals occur in it, and it shows sun-cracks similar to those of the blue shales of the Fletcher dam. The thickness exposed is about four feet, but the total thickness is probably much greater.

This stratum is succeeded by a foot of grayish subcrystalline limestone, full of a small variety of *Cyrtina umbonata,* identical with that found in a similar bed overlying the clay of Dock street northeast of Alpena (Loc. 1c). Judging from the appearance of the rock and the fossils alone, these two beds may be readily correlated. That they are

the same bed is, however, not proven. On the right bank of the river, below the dam, six feet of the bluish shales (which at times become somewhat strongly calcareous, but generally have a distinct shaly character and show sun-cracks) are shown, overlain by the Cyrtina bed. Some of the upper beds of this blue shale series are of a more calcareous character, and weathered to a brownish color. They then resemble the upper beds of the Fletcher dam series, but they are quite certainly not equivalent.

Above the Cyrtina bed, on the left bank, are again about six feet of bluish shales, similar to those below, but somewhat more fissile. These are practically unfossiliferous, as far as has been ascertained, and are overlain by calcareous beds which become more and more fossiliferous near the top. The upper beds are weathered, where they are uncovered in the building of a road, and here a large collection of fossils was obtained. Among the species abundantly represented are: *Spirifer mucronatus, Athyris fultonensis, Atrypa reticularis, Spirifer granulosus, Pentamerella dubia, Cyrtina hamiltonensis* (small but robust type), *Stropheodonta demissa, Cyrtina umbonata alpenensis.*

Among the rarer species are: *Camarotoechia* cf. *dotis, Stropheodonta nacrea, Cryptonella rectirostris, Eunella lincklaeni,* Conocardium, Pleurotomaria (several species), *Phacops rana, Striatopora rugosa,* Pentremites, tegminal spines of crinoids, etc.

The relation of these shales to those of the preceding locality is not quite clear. Rominger considers them below those of Fletcher dam, and makes the former series about 50 feet thick. This relation is probably the true one, but needs verification. The great similarity of the Cyrtina bed near the base of this section to that found overlying the Dock street clay, suggests their identity. If this is the case, and the beds of the Fletcher dam overlie those of the present section, the lower part of the Thunder bay series, from the Alpena limestone to the coral bed of Fletcher's dam, is not over 70 or 80 feet, if as much. As will be seen from a comparison of faunas, there are good reasons for believing that the shales of the Warner brickyard (Loc. 25) are the same as those exposed at Fletcher dam. This correlation is, however, only a tentative one and requires verification in the field.

Loc. 25. Warner brickyard. This locality is in the southwestern portion of Alpena, and about due northwest of Stony Point. The top bed here consists of about a foot of thin-bedded limestone, frequently with shaly partings, and quite fossiliferous, containing the following characteristic species: *Dolatocrinus triadactylus, Striatopora rugosa, Codaster* cf. *canadensis,* a large Fistuliporoid bryozoan (which is very common), and *Craspedophyllum archiaci.* This species occurs commonly in slender, isolated fragments, as at Fletcher dam, and associated with it is the small clustered species of Ceratopora (?) found at that locality. Other species found in these beds are: *Orthis (Schizophoria)* cf. *propinqua* (small), *Rhipidomella vanuxemi* (?), *Atrypa reticularis* (common), *Spirifer audaculus, Gypidula romingeri* (young), *Pentamerella papillionensis* (?), *Cyrtina hamiltonensis, Stropheodonta* cf. *costata* (rare), Cryptonella, Zaphrentis, Aulopora, *Favosites alpenensis, Dendropora alternans,* Fenestella, Loculipora.

Below these calcareous beds are shales with occasional bands of argillaceous limestone, the latter only a few inches thick. In the exposed portion the shales have weathered to a brownish gray, but lower down they

are blue. They are highly fossiliferous, Bryozoa predominating. The following species have been noted:

Athyris fultonensis (common), *Atrypa reticularis,* Spirifer, *Eunella sp., Striatopora rugosa, Dendropora alternans,* Ceratopora, *Dolatocrinus triadactylus,* Fenestella, Loculipora, other Bryozoa, Crinoid stems.

The association of species suggests that these beds are the same as those exposed at Fletcher dam. This seems to be particularly indicated by the abundance of *Craspedophyllum archiaci,* which nowhere else has been noted in equal abundance. The beds of these two localities are provisionally correlated, but this correlation must be verified. They are in proper alignment along the strike of the strata. The following analysis of the blue shale of the Warner brickyard was kindly given me by Mr. Monaghan:

ANALYSIS OF THE WARNER BRICKYARD CLAY.

		The same with the Ca and Mg calculated as carbonate.	
SiO_2	54.46	SiO_2	54.46
Al_2O_3	17.26	Al_2O_3	17.26
Fe_2O_3	4.66	Fe_2O_3	4.66
CaO	6.60	$CaCO_3$	11.79
MgO	2.82	$MgCO_3$	5.92
	85.80		94.09
Difference CO_2 organic matter, alkalies and loss	14.20	Difference largely organic matter and alkalies	5.91
	100.00		100.00

Loc. 22. Stony Point. This is on the shore of Lake Huron, just south of Alpena and southeast from the preceding locality. The surface of the country over an acre or more exposes ledges of a gray, argillaceous limestone, with numerous weathered-out corals, chief among which are *Craspedophyllum archiaci,* Stromatopora, Favosites, *Cyathophyllum travensense,* etc. The rock extends perhaps 50 feet out into the lake, after which it is lost to view. Rominger mentions quite an extended list of fossils from this locality (loc. cit. p. 42). As before noted, the Stony Point ledges lie 80 feet or more above the Alpena limestone. If, as there is reason to suppose from the correspondence of the faunas, the Stony Point and Fletcher dam limestones are equivalent, the shales and limestones included between the basal members at the latter locality and those at the Boom company's dam must have a thickness of from 60 to 70 feet, provided the Cyrtina bed at the base of the Boom company's dam is equivalent to that of Loc. 1 and, like it, not over 10 feet above the Alpena limestone. If this is the case, the beds which yield the rich brachiopod fauna of Loc. 24 lie about midway between the Stony Point and Alpena limestones.

Loc. 23. Partridge Point. At this locality the highest beds of the Thunder bay series are exposed, the overlying black St. Clair shales appearing on Sulphur Island, southeast of the point. No exposures have been noted between this locality and Stony Point, and the character of the intervening strata, some 50 feet or more in thickness, is still unknown.

The cliff facing the lake at Partridge Point is about 12 feet high and covered with a foot or more of shell-bearing gravel. The upper beds of the series are poor in fossils, *Spirifer mucronatus* being about the only species found. The limestone of the upper four or five feet of the cliff is thin bedded and more or less lenticular, with shaly partings between the layers. The beds consist mostly of irregular lenses a foot or more

in diameter and of unequal thickness. These limestones are dark bluish-gray on fresh fracture, but weather yellow and brown. They generally consist of comminuted crinoid stems and small corals (Favosites, etc.), with comparatively few brachiopods (*Atrypa reticularis, Meristella rostrata, Camarotoechia,* etc.).

Three and a half to four feet from the top of the cliff is a more or less continuous layer of Cystiphyllum, with occasionally other large rugose corals. This has been traced the entire length of the section, but the corals are most abundant near the middle portion. All the corals are prostrate. For about a foot above and below this layer, Pentremites, Codaster, Nucleocrinus, Dolatocrinus and Megistocrinus occur not infrequently.

Among the limestone beds corals of the genera Favosites and Craspedophyllum are common, the former being represented by various species, including *F. alpenensis* and *F. placenta* of the type found at Fletcher dam. Craspedophyllum is represented by *C. caespitosum* and *C. archiaci.* Cystiphyllum, Cyathophyllum and Stromatopora of various species are likewise common, and large heads of Syringopora are not infrequently met with. One of these measured over two feet in diameter. Bryozoa are also common. In some layers, particularly the shaly ones, brachiopods (*Meristella rostrata, Cyrtina umbonata, Athyris fultonensis,* etc.) predominate, though these are never very abundant.

The lower portion of the cliff consists of shales with thin-bedded calcareous layers. These are readily worn away by weathering and wave attack, and the more resistant beds above project. The undermining is a comparatively rapid process, and falls of rock masses from the cliff above occur almost nightly.

The shaly layers contain few fossils, but the interbedded calcareous layers are rich in them. Some of these latter appear to be made up of Bryozoa, particularly the frondose types (Fenestella, Polypora, Loculipora, etc.), and these are often beautifully preserved, not infrequently showing something of their original contour. Trilobites are rare, only a few specimens of *Phacops rana* having been found.

The capping beds of the Traverse group of this region consist of a brownish granular dolomite of considerable hardness. These beds, 10 feet of which are recorded in well No. III,—1, are exposed along the shores of Thunder bay on the south side of Partridge Point. In the absence of fossils, it may be indifferently referred to either the Traverse or higher beds. It is here included in the former group.

No exposure of the black shale has been found on Squaw bay, its occurrence there resting on the authority of Dr. Rominger. The shale, however, is prominently exposed on Sulphur Island.

LITTLE TRAVERSE BAY REGION.

A.—WELL RECORDS.

Only a few wells have been put down in the Petoskey or Little Traverse bay region, and of only one of these, the Charlevoix well No. 3, have I seen the samples.

Bay View Well.

Reported by H. P. Parmelee and A. J. Richards. Completed July, 1895.

This well is 120 paces northwest from the door of the G. R. & I. R. R. Bay View station, 4½ feet above the bay, and 40 feet from the shore. The record is as follows:

0— 4	Shingle.
4—264	Cream limestone.
264—462	Medium grey limestone
462—473¼	Dark limestone.
473¼—498¼	25 feet of cellular blue shale.

Flow, 200 bbls. an hour.

At 450 feet depth a hard stratum was found, in which only a foot and a half a day could be drilled. Beneath this the water was struck. In all the rock, except this indurated bed, the drillings were from 10 to 12 feet per day.

Petoskey Well.

H. P. Parmelee, Charlevoix; C. S. Hampton, G. S. Richmond, Petoskey. Drilled in 1888.

This well is 33 feet north of the Chicago & West Michigan railroad station, near the end of Lake stret, Petoskey, and 180 feet from Bear river. A flow of sulphuretted water, relatively low in NaCl, was obtained.

The well is drilled in an old drift-filled valley, or rock gorge, for rock is found in place five feet from the surface on either side.

The following record was obtained:

Feet.	
0 to 30.	Glacial gravel, etc.
30 to 280.	Limestone strata, highly fossiliferous throughout the entire depth. The fauna is nearly the same as that found in the surface bed. Color light gray, a few strata quite dark and much harder.
280 to 295.	Ten to 15 feet of blue shale, no fossils. Beneath this was a flow of quite pure water, somewhat charged with H_2S.
295 to 355.	A nearly solid bed of Acervularia limestone, without a trace of mollusca or other corals. Color light, often creamy white.
355.	A thin layer of gray lime rock of incoherent structure.
355 to 435.	Dark shale 80 feet in thickness, equivalent to Bell shale.
435 to 555.	About 120 feet of crystalline limestone (Dundee limestone) of same color, texture and composition throughout.

Charlevoix Wells.

Three wells were put down in Charlevoix within 50 feet of each other. I have examined the samples of well No. 3 and from it obtained the following record.[46] The upper 230 feet were of unconsolidated material, showing the existence of an old buried valley under Charlevoix.

[46] See Water Supply Paper No. 31, p. 87. The beds down to 300 feet are rather dolomitic. L.

Record of Charlevoix well:

Feet.	
0 to 230.	Drift, subdivided as follows: 0 to 6 feet. Sand. 6 to 15 feet. Gravel. 15 to 170 feet. Fine sand. 170 to 176 feet. Gravel. 176 to 230 feet. Sand; quicksand at 214 feet.
230.	Fine-grained earthy limestone, effervescing with dilute HCl. It is identical in color and texture with bed f of Loc. 39, but the characteristic plant remains of that rock are absent. It also agrees with some of the darker portions of bed g, Loc. 39. No fossils found in the samples.
240.	Gray limestone, agreeing in color and texture with bed e, Loc. 46. It effervesces freely with dilute HCl. No fossils in samples.
250.	Earthy or chalky, brownish, porous, much oxidized clayey limestone with a strong clay odor, being in fact in large part clay, but with sufficient lime to give it coherence, and cause free effervescence with dilute HCl. It corresponds in texture with the lowest bed of Loc. 48, but is darker and somewhat more porous. The same pieces when broken are of an ochre color.
260.	Dark gray argillaceous and somewhat shaly limestone, effervescing freely in dilute HCl. Similar to but more earthy than bed e, Loc. 36.
270.	Finely stratified shale, effervesces feebly with strong HCl. Compact in texture.
280.	Fossiliferous whitish limestone, containing *Atrypa reticularis* and other fossils. It effervesces freely with dilute HCl.
290.	White crystalline limestone containing considerable crystalline calcite. It carries fragments of *Acervularia davidsoni*. The rock is of the same type as bed g, Loc. 39, but is whiter than that rock and somewhat more crystalline. Some portions of the samples are compact and argillaceous.
300.	White chalky limestone, non-argillaceous, fossiliferous, and effervescing freely with dilute HCl.
315.	Brownish, earthy and argillaceous limestone, with a strong clay odor; Bryozoa and other fossils have been observed. It effervesces freely with dilute HCl.
322.	Gray calcareous clay of very uniform texture, partially oxidized. It effervesces freely in dilute HCl, but is nevertheless a good clay.
330.	Gray, compact calcareous clay rock, but of massive character, and effervescing freely in dilute HCl.
335.	Fragments of *Acervularia davidsoni* with the calices free from matrix, and evidently embedded in clay. No clay is, however, retained.
345.	Gray calcareous shale, mixed with pure white limestone, the latter containing Favosites and Acervularia.
350.	Gray argillaceous limestone, and some white limestone, with fragments of Spirifer and Acervularia.
355.	Gray limestone. *Acervularia davidsoni* is abundant. Favosites and *Atrypa reticularis* also occur.
360.	Gray, compact, semi-argillaceous limestone; fossils not observed, except crinoid stems. Much shale is mixed with the limestone.
367.	Fragments of *Acervularia davidsoni* and Favosites.
370.	Compact, gray, argillaceous limestone; no fossils observed. It is almost a clay.
375.	Fine-grained, compact, argillaceous rock, not unlike the lower beds of Loc. 42 or those of Loc. 43.
387.	Limestone and black shale.
390.	Gray argillaceous limestone with whiter limestone containing Acervularia.
400.	Chalky clay. Crumbles and soils fingers. Cream colored.
402.	Bluish gray clay, slightly calcareous, effervescing feebly with HCl.
410.	Compact, brown to gray limestone, weathering earthy.
415.	Cream colored calcareous clay, identical with the rock at 400 feet,
420.	Limestone similar to that at 410 feet. No fossils.
430.	Cream colored earthy clay, somewhat more calcareous than that at 402 feet.
443.	Brown banded limestone, mingles with black and gray shale containing *Atrypa reticularis*, etc.
447.	Bluish clay, non-effervescent.
460.	Same as preceding.
470.	Same as preceding.
482.	Same as preceding.

No fossils have been observed in any of the samples of blue clay seen.

B.—RECORDS FROM OUTCROPS.

The outcrops studied are along the shore of Little Traverse bay, on the northwestern side of the Lower Peninsula of Michigan. It is from this region that the formation derives its local name. The outcrops are much less satisfactory than are those of the Alpena region, and the rocks are much less fossiliferous. The shore of the bay extends along the strike of the strata, and hence nearly the same beds are exposed in the various

sections. Only in the southwestern portion of the shore line, where the shore trends across the strike, is a rapid stratigraphic ascent made. Owing to the existence of a number of minor folds or undulations whose axis is normal to the strike of the strata, a number of beds which would otherwise be below the water level are brought to the surface. The thickness of the exposed beds is not much over 100 feet, while the total thickness is probably between 550 and 600 feet. The exposures begin about a mile and a half east of Petoskey, near Bay View, and extend with numerous interrruptions to near Norwood village, beyond which the Black shales appear on the shore. The total distance along the shore from the point of first appearance* to the final disappearance of these strata is over 30 miles. What the normal dip of the strata of this region is has not been ascertained.

Loc. 38. Opposite Bay View station. In the building of a road at this locality about four feet of limestone were quarried near the lake. These, with similar beds shown at the bottom of the bay, are among the highest beds of this region. They are thin-bedded argillaceous and bituminous limestones, often with thin, shaly partings. Bituminous matter is common, and the rock often smells strongly of petroleum. When weathered, as near the surface, it is porous, soft and friable, and deeply stained by iron hydrate. The fossils, *Spirifer mucronatus, S. consobrinus* (?), *Cyrtina hamiltonensis, Stropheodonta crratica, Productella,* Bryozoa, etc., generally stand out in relief, being more or less silicified. Some slabs of the rock are covered with coarse intersecting ridges, of the thickness of a finger or less, which may represent casts of marine algæ or may be those of large sun-cracks. They are unjointed, and cross each other at all angles.

The same strata are shown in a cutting behind the beach, near the railroad. The upper beds here are a fine, uniform-grained, non-fossiliferous rock, smelling strongly of petroleum. It has been weathered yellow and become very soft, being easily crumbled between the fingers.

Loc. 39. Petoskey. In the first quarry, near the northeastern end of the section, the following succession of strata is shown. In the eastern end the dip is northeastward, while further west it is four degrees to the southwest:

a. The lowest bed exposed is a dark, grayish-brown, fine-grained, friable limestone, freely effervescing in dilute HCl, porous and with a strong petroleum odor: 4′.

b. Light, creamy-gray, fine-grained limestone, freely effervescing in dilute HCl, soft and porous and with the stratification line marked by bluish bands occurring at intervals. It contains a few pelecypods (Edmondia?) and occasionally Favosites: 4′.

Between this and the next overlying stratum is an inch or two of shaly matter.

c. Porous, fine-grained limestone, weathering dark brown. Near the western end of the quarry it constitutes the lowest bed: 3.5′.

This bed is separated from the one next above by three or four inches to a foot of shaly rock. The shaly partings are frequently carbonaceous, thin films of the coaly matter covering the laminæ. No plant remains have been identified. Bed c is much like bed a. It contains similar car-

* For the position of the relative outcrops see the map, Plate VIII.

bonaceous films, and has also a bituminous odor. It is very soft and friable in places.

d. Lighter colored limestone, similar in all respects to bed b. No fossils found. Stratification is well marked, and bituminous films are common: 3.75′.

c. Similar rock, but filled with small masses of Stromatopora. The aspect of this mass is that of a brecciated limestone, or like a conglomerate in which the pebbles are fragments of coralline. Where the rock has been exposed to the weather for some time it is rough surfaced, with numerous solution hollows: 26′.

In some parts the lower four or five feet are like the rock below,—massive and uniformly fine-grained, with few or no fragments of Stromatopora. In most places, however, the rock is full of this fossil throughout, being in fact a coral breccia. The Stromatopora fragments are of all shapes and sizes, often angular, and so far as observed never entire. A fragment, with the abruptly cut-off layers of growth, is illustrated in the annexed figure. Solution seems to have gone on to a considerable extent in these heads before they were buried by the coral sand which now forms the limestone. Cracks and solution cavities are not uncommon in the coralline masses, and these are filled by the coral sand.

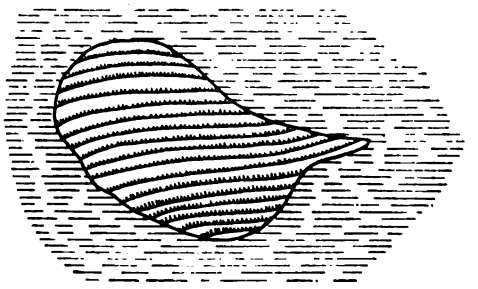


Fig. 3. Section of a worn Stromatopora head.

The Stromatopora are not the only fossils. Cyathophylloid corals, Favosites, Conocardium and others have been found, and are sometimes common.

The majority of the Stromatopora masses lie overturned, or in some other abnormal position, which clearly indicate motion. The matrix in which the masses of coral are embedded is of a sugary character, rather soft and crumbling, and effervesces freely in dilute HCl. The fossils which it contained are mainly dissolved out, and the cavities often lined with calcite crystals. No analyses have been obtained,* but report credits this rock with a high per cent of $CaCO_3$, which in some instances approaches 100. Some specimens of *Atrypa reticularis* have been obtained from the upper portion of this stratum. This stratum may be traced along the railroad track to within a short distance of the railroad station.

* The following commercial analysis was published by E. R. Sly:

$CaCO_3$	91 25
$MgCO_3$	4.00
Balance	4.75
	100.00

Mr. H. P. Parmelee says that it runs up to 96 per cent L.

f. Overlying the Stromatopora bed is a cream-colored limestone, which appears much shattered in the cliff. Fallen blocks, which appear to be from this bed, are of an earthy, rather argillaceous character, effervesce freely in dilute HCl, and contain numerous carbonaceous films representing narrow, reed-like plants. Other fragments, apparently from this bed, contain Favosites, but rarely other fossils. The bed is inaccessible. Estimated thickness, 4.5′.

g. This is the highest bed in this section. It consists of a granular lime-sandstone* of a sandy feel, and effervesces freely dilute with HCl. It is somewhat darker than the rock below and contains numerous large coral heads, which apparently grew where they are now found. *Diphyphyllum panicum* makes up the greater portion of the bed. It occurs in abundance at the foot of the cliff, and must have fallen from above. The species appears to be restricted to this bed. Associated with it is Cystiphyllum and Favosites, while *Atrypa reticularis* and *Gypidula romingeri* also occur, though sparingly. The thickness of this bed is estimated at 5.6′. The top of the cliff is formed by a layer of stratified sand several feet in thickness.

The total exposure of rock in this section is 50 feet.

These beds are the Stromatopora beds of Winchell, who considered them the lowest of the series. Rominger, on the other hand, considered them as belonging to the higher members of the group, and with this view I concur. As will be shown below, the name Stromatopora beds is not applicable to other exposures of this series, where the prevailing coral is Acervularia, while in some portions fossils are entirely absent. The name Petoskey limestone is more serviceable for purposes of correlation, since these beds are so finely exposed at Petoskey. Moreover, beds at a lower horizon are fully as rich in Stromatopora, and would equally well deserve the name.

Loc. 40. About a mile west of the mouth of Bear creek, ledges are exposed at the water edge, consisting of a thin-bedded, fossiliferous limestone. The lowest beds seen are somewhat shaly in character and are crowded with large shells of *Stropheodonta nacrea.* Associated with them is *Spirifer mucronatus,* which is likewise abundant. Overlying these beds are gray limestones containing *Acervularia davidsoni,* Favosites and crinoid stems, besides other fossils. Next above these limestones gray, calcareous shales occur again, in which *Stropheodonta nacrea* is the prevailing species. *Spirifer mucronatus* and *Atrypa reticularis* occur with it.

These beds are so well characterized by the prevailing fossil, *Stropheodonta nacrea,* which is an easily recognized form, that for purpose of reference I shall call them *Stropheodonta nacrea* beds. They will be referred to again in other sections, where they are apparently exposed again. These are the lowest of Winchell's "Tropidoleptus beds" (loc. cit. p. 42), the upper beds being those of locality 41. In the supplement to his report, Professor Winchell changes the name to Bryozoa beds, since the supposed Tropidoleptus proved to be a Stropheodonta (*S. erratica*). Winchell assumed that these beds and those of the next locality, which overlie them, were stratigraphically above the Stromatopora beds of Petoskey. This is probably an error, for the well sections show the upper beds of this region to be of the type exposed in the Petoskey quarries.

* The term lime-sandstone is used throughout for rock made up of coral sand, i. e. a fragmental limestone.

These beds furthermore appear to underlie those carrying the Acervularia clays (Acervularia beds of Winchell), since a continuous section at Loc. 46 from these clays into the Petoskey limestone does not reveal them.

Loc. 41. About one and one-half miles west of the mouth of Bear creek is a low bluff, about twelve feet in height, and extending for several hundred feet parallel to the shore, and a short distance behind it the cliff shows gray, fine-grained limestone beds with shaly partings, often several inches in thickness. These limestones contain *Acervularia davidsoni, Favosites* cf. *alpenensis, Atrypa reticularis, Strophcodonta nacrea* (of large size, occurring chiefly in the more argillaceous portions of the rock), *Pentamerella* cf. *dubia,* and *Spirifer mucronatus,* besides Stromatopora and other fossils. The black parting shales contain *Pterinea flabellum, Stropheodonta erratica,* and Modiomorpha. The limestone is dark-gray, fine and uniformly grained, weathering to a light-gray color. It effervesces freely with dilute HCl, and has an argillaceous odor, a clayey residuum remaining on weathering. The masses of coral in it are generally more or less worn, and the contact between them and the matrix is a sharp and regular one, showing that the fragments have been rolled about and worn smooth. This shows that at least some of the coral heads were dislodged from their anchorage, and marks this limestone as probably formed on the outer portion of the growing reef.

The dip of the strata is as high as ten degrees to the northeast. This is near the southwest end of the bluff; in the northeastern end the dip is more nearly horizontal.

These beds are No. C of Winchell's section, with possibly a portion of his higher beds.

Loc. 42. This locality is described by Winchell as situated in the S. W. ¼ of Sec. 2, T. 34 N., R. 6 W., Loc. 861. The section begins about two and one-half miles west of the mouth of Bear creek, and between it and the preceding locality is a long, high drift-bluff, with no rock exposures. The bluff at the eastern end of the section is about fifteen feet high, and at its foot is a talus of four or five feet. The highest bed of the section is exposed at the eastern end and is designated bed I. The succession from above downwards is as follows:

42I. The upper beds of the section consist of a bluish calcareous shale, which weathers into a brownish-gray clay and contains many fossils, which may be collected on the talus. Chief among these are *Spirifer audaculus,* a small but strongly spinous species of Productella, *Atrypa reticularis, Stropheodonta erratica, Favosites alpenensis, Acervularia davidsoni,* Cyathophyllum, and Hederella; also from blocks probably from this bed: *Cyathophyllum traversense, Gypidula romingeri, Phacops rana, Craspedophyllum archiaci,* Platyceras, and others. Thickness, 4′.

42H. Next below this is a limestone with shaly partings between the beds, especially in the lower portion. It contains numerous corals, among which Acervularia predominates: 6′.

42G. Next below this and forming the lowest bed in the eastern portion of the cliff, is a gray, porous lime-sandstone, consisting of fragments of brachiopods and other organisms finely comminuted. It is somewhat petroliferous and has a sandy feel. *Stropheodonta erratica* and other brachiopods and a few corals have been observed in it: 6′.

The dip of the strata in this region is from five to six degrees to the northeast, i. e., towards Petoskey.

These strata may be traced westward for half a mile or more to Rose's* quarry, where a deep section is opened, exposing the lower members of this series. Before reaching the quarry, bed G and the overlying ones have been cut off owing to the steady westward rise of the strata. At the quarry the axis of the low anticline in which these beds are involved is located, beyond which the strata dip westward. At the axis the upper beds have been worn away down to the blue clay, bed D.

42F. Blue clay, rich in fossils. In every respect except thickness like bed D: ¾′.

42E. Limestone with Acervularia, cup corals, and other fossils, which occur chiefly near the top of the bed, where it is more shaly. The limestone is dark-gray, fine-grained and crystalline: 1¼′.

42D. Blue, highly fossiliferous clay, rich in fossils, among which the following are the most characteristic: *Acervularia davidsoni*[47] (well-preserved, complete heads up to six inches or more in diameter), *Cyathophyllum traversense,* and *Favosites alpenensis* often in large heads. Other species of common occurrence are *Stropheodonta costata, Pentamerella* cf. *papillionensis, Athyris fultonensis, Terebratula traversensis, Cyrtina hamiltonensis, Eunella lincklaeni, Atrypa reticularis,* and a number of others. The thickness of the clay is 3′.

This is the bed more particularly designated as Acervularia bed in Winchell's section.

42C. Shaly argillaceous blue limestone, sometimes in several layers near the top, with thin shale partings: 2′.

42B. Compact, creamy-gray, fine-grained limestone with conchoidal fracture. This contains numerous heads of Stromatopora, all apparently perfect, and ranging in size up to two or three feet. The rock is much shattered and looks concretionary, owing to the presence of the Stromatopora. The latter is generally surrounded by a film of carbonaceous matter, which appears to be the original animal matter. At the top of this stratum, and also at intervals within it, are thin beds of black carbonaceous shales (sometimes stained brown by iron hydrate), and full of flattened shells of *Stropheodonta erratica,* with a few other fossils. The thickness of this stratum is about 5′.

42A. Cream-colored limestone similar to the preceding, but lighter colored. It is fine-grained, compact and with conchoidal fractures, and

* Now property of Michigan Lime Co.

47 The statement is frequently made that our species, identified with the European *Acervularia davidsoni,* E. & H., has no secondary wall, and that hence our species is not Acervularia. Rominger placed it under Cyathophyllum, while Simpson (Bull. N. Y. State Museum No. 39, 1900, p. 218) has originated the new genus Prismatophyllum, with *Cyathophyllum rugosum* as the type, and placed this species under it. It is true that there is no real secondary wall in our species, the appearance of such a wall being produced by the uniform arrangement of a circle of dissepiments, and the stoppage of the shorter septa at this point. But this is also true of typical European species, in which the longer septa and often the ends of the shorter septa also pass beyond this wall of cysts. Whether such a wall is or is not the morphologic equivalent of the secondary wall of Craspedophyllum and Diphyphyllum, where the septa do not extend beyond that secondary wall, does not affect the question as to the generic equivalence of the American and European species. If we regard the prismatic species of Cyathophyllum as congeneric with Acervularia as represented by American species,—as Rominger, Simpson and others have done,—all of these species should be placed under the genus Acervularia, and Simpson's generic name Prismatophyllum becomes a synonym. I believe that Simpson is right in separating the prismatic species generically from Cyathophyllum. The name *Acervularia davidsoni* has been retained for the present for our species, leaving the exact generic and specific determination for future investigation.

effervesces freely with dilute HCl. A few specimens of Favosites and other fossils have been seen. The beds are from one to two feet thick, and some of them are separated by thin bands of brown, bituminous shales. Thickness exposed, about 8′.

These beds, though in some respects similar to the limestone of Petoskey, are from fifty to a hundred feet below it. The abundance of Stromatopora in bed B might lead to a confounding of these two beds the one with the other. In the present bed the Stromatopora heads lie in normal and apparently undisturbed position, while those of the Petoskey limestone are nearly always worn and fragmentary.

Loc. 43. Nathan Jarman's quarry, Petoskey. The location of this quarry is in the N. W. ¼ of the S. W. ¼ of Sec. 6, T. 34 N., R. 5 W. This quarry was opened in the hillsides above Petoskey at an elevation of about 80 feet above the lake, and distant from it about half a mile. The succession is as follows from above down:

43B. Light gray, compact limestone, much shattered in the quarry and in places thin-bedded, with occasional thin carbonaceous films. The rock has a conchoidal fracture, and effervesces freely in dilute HCl. No crystalline structure is shown under the microscope, the mass being extremely compact and fine-grained. Fragments of organic remains and calcite veins occur. Thickness exposed, 12′.

43A. Darker, fine-grained, somewhat more crystalline limestone, with petroleum odor: 6′.

Below this are other beds of similar quality, with some carbonaceous films.

These beds probably represent the lower portion of the Petoskey limestone, similar to those shown in the quarry at Petoskey. At the shore below this point the beds of Loc. 41 are exposed. The interval between these beds appears, therefore, to be in the neighborhood of a hundred feet,—taking into consideration the southward dipping of the strata over the half-mile interval.

Loc. 44. About a third of a mile west of the point where section 42 was measured (Rose's quarry), limestones crop out on the beach.

1. The first beds seen are apparently at some considerable depth below the limestone 42A. It is a dark, crystalline but fine-grained, compact limestone, with brachiopods (*Atrypa reticularis,* etc.) sparingly represented. It dips 10 degrees northeast.

2. Ledges are shown at intervals under the water of the bay, in going westward. Those clearly belong below the preceding. Some five feet or more of these limestones are shown in a series of low anticlines. About half a mile further west, the following section has been opened in a small quarry on the shore:

A. The lowest beds are gray, crystalline and somewhat fossiliferous limestones, rather shaly in the upper portion, and containing large heads of Acervularia and Stromatopora, over which the strata arch as on Thunder Bay Island. Some thin layers of black, bituminous, shaly limestone, with a strong petroleum odor, occur toward the top: 18 in.

B. Limestone similar to A, in beds from 6 inches to a foot in thickness. No coral heads seen: 3′.

C. Beach material.

Along the beach occur many slabs of shaly limestone containing *Stro-*

pheodonta nacrea in abundance. These are from ledges near by, but probably submerged.

For perhaps two miles along the shore, rock is exposed at the water's edge, with a few interruptions by sand and shingle beach. The dip of these strata vary in direction and amount, disclosing many small anticlines. Along a portion of this distance the dip is toward the shore at an angle of nearly 10 degrees. As the shore is along the strike of the strata, no great stratigraphic ascent is made. The *Stropheodonta nacrea* beds are represented by fragments all along the beach, and the beds are occasionally in place. Limestones with Acervularia and occasionally Stromatopora and Favosites, as well as other corals, crop out continually and appear to be closely related to the *Stropheodonta nacrea* beds. The total thickness of beds exposed appears to be not much over 10 feet, though this estimate may be far short of the truth.

The *Str. nacrea* beds of this locality are dark-gray, argillaceous, thin-bedded, shaly limestones, crowded with the *S. nacrea,* which is of large size. *Spirifer mucronatus* occurs with these, but other fossils are rare. The similarity of these beds to those of Loc. 40 is very striking, both in lithic and faunal characteristics. In both localities shaly strata, crowded with *Stropheodonta nacrea* and containing *Spirifer mucronatus,* are associated with limestones carrying Acervularia and Stromatopora. There are probably several alternations of such beds, aggregating a thickness of perhaps some 10 or 20 feet, or perhaps more. But I do not think that there is more than one horizon in this group where these strata occur. If the correlation of these strata with the beds of Loc. 40 is correct, it is probable that the lower bed (A) in the quarry on the beach is the equivalent of bed A of Loc. 42. The occurrence of Stromatopora *in situ* suggests this equivalency.

It must, however, be borne in mind that correlation of beds in isolated outcrops, and with only a few paleontological characters to relie on, is a very unsatisfactory matter, and the correlations here made should be considered as tentative and subject to revision.

Loc. 45. This is about half a mile east of the next locality, and is a cliff 10 or 12 feet high, with the base talus covered. The upper portion is a shattered drab limestone with numerous heads of Acervularia and Stromatopora, some of which are very large. The rock closely resembles bed B of Loc. 42. Below it is a similar though more compact rock. It contains black carbonaceous seams, which appear more particularly near the top of the bed. The cliff is nearly continuous with that of:

Loc. 46. This is at the Bay Shore Lime Company's first quarry. It is in Emmet county, four miles west of Petoskey or two and one-half miles east of Bay Shore. The locality is that described by Winchell under 862 (p. 45), and located in the S. W. ¼ of Sec. 4, T. 34 N., R. 6. W. Rominger also described this section (p. 57). The following is the succession, from the top downwards:

46K. Blue clay covered by drift, fossils not observed.

46J. Limestone, compact, dark and somewhat argillaceous, with Stromatopora and Acervularia, the former chiefly in the upper portion. All lie with their longer diameter parallel to the stratification, and are usually broken and worn. They are frequently overturned, and in general are much like the rock of Rose's quarry at Petoskey (Loc. 39): 16′.

This rock is burned for chemical works, the burning being from 9 to 12

hours, and on the average 750 barrels are burned per week. The rock effervesces freely in dilute HCl. The dip of the bed is 5 degrees east.

46H. Blue clay with *Acervularia davidsoni. Favosites alpenensis, Stropheodonta crratica,* and many other species of the same type found in 42D, to which bed it is undoubtedly equivalent: 1¼′.

46G. Compact limestone like 46I, with Favosites, Zaphrentis, etc., well stratified: 1½′.

46F. Black carbonaceous shale with Favosites, etc.: 2 in.

46E. Compact gray limestone with Zaphrentis, Favosites, and complete heads of Stromatopora: 1′.

46D. Black carbonaceous shale, fissile, with *Stropheodonta crratica:* 5 in.

46C. Stromatopora bed with large heads from two to three feet in diameter, mostly perfect and commonly covered on their upper surfaces by a carbonaceous film. Small Favosites and a few other corals also occur. This is the equivalent of bed B of Rose's quarry (Loc. 42). In some parts it is a regularly stratified limestone with scarcely any Stromatopora: 8′.

B. Black carbonaceous shale; no fossils seen: 1 to 2 in.

A. Compact limestone, with broken and worn fragments of Stromatopora lying in all positions; in beds from one to two feet thick, separated by carbonaceous black shale 2 to 5 inches thick; exposed 4-5′.

Loc. 47. Bay Shore Lime Company's second quarry, near Bay Shore. This locality is in the Buff Magnesian beds of Winchell, which he supposed to be next to the highest in the series. In this he was correct, but he erroneously placed these, and the underlying Acervularia and Bryozoa beds above the limestones of Petoskey (the Stromatopora beds). There can be little doubt from the present more satisfactory exposures, and the well records, that the "Stromatopora" and "Buff Magnesian" beds are equivalent. This equivalency was held by Rominger.

The cliff in the quarry consists of about 12 feet of porous, dolomitic, brown limestone, which effervesces feebly with strong HCl and gives off a strong petroleum odor. Under the microscope it shows a finely crystalline structure, the crystals being stained by iron oxide. Apparently overlying this rock, but only exposed at one locality, is a coarsely crystalline limestone, loose textured and consisting largely of fragments of crinoid stems. The cliff continues, with slight interruptions, to Bay Shore.

Loc. 48. This is the third quarry of the Bay Shore Lime Company, at Bay Shore, and forms the end of the Khagashewung Point section of Rominger. The following section is opened in the quarry, the thickness of the upper beds being estimated:

Drift		5—10 ft.
48 f.	Brown earthy dolomite (?)	6— 8 ft.
e.	Drab dolomite (?) breaking with square blocks	3 ft.
d.	Yellow saccharoidal dolomite (?)	2 ft.
c.	Grey dolomitic limestone like (e)	2 ft.
b.	Grey banded saccharoidal dolomitic limestone	10 ft.
a.	Brown earthy limestone, effervescing freely in dilute HCl	10 ft.
		35 ft.

The porous earthy beds usually give off a strong petroleum odor when freshly broken. No fossils have been observed in any of the beds during the hurried examinations made.

The dolomitic character of the upper beds of this series has not been

verified as yet by chemical tests. Some of them may be limestone. Rominger, however, gives an analysis of one of these beds (exact position not given) which proves that some of them are at least good dolomites. The analysis gives:

	Per cent.
$CaCO_3$	58
$MgCO_3$	38
Al_2O_3, Fe_2O_3	1.5
Insoluble residue chiefly SiO_2	0.5
	98.00

A number of exposures occur between Khagashewung Point (Bay Shore) and Pine River Point, three miles west of Charlevoix pier. These have not been studied as yet. A description of some of these is given by Rominger, from which it appears that the *Stropheodonta nacrea* beds crop out again.

Loc. 49. Pine River Point, three miles west of Charlevoix pier, is located in the N. W. ¼ of Sec. 28, T. 35 N., R. 8 W.

The limestones first appear on the beach in low anticlines, and are of a compact texture and dark color. They contain few fossils in the lower part, but higher up *Favosites* cf. *alpenensis, Acervularia davidsoni, Atrypa reticularis,* Spirifer, etc., are found. Beyond this are low cliffs, not more than five feet high, and rising to a height of 10 feet above the lake. They consist mainly of shaly limestones, with an occasional hard, compact bed less than a foot in thickness. The shaly beds are rich in fossils, especially *Stropheodonta nacrea,* while *Spirifer mucronatus* and *Atrypa reticularis* are likewise abundant. Another common species on certain layers is *Chonetes emmetensis.* This is closely related to *Chonetes mucronatus* which is characteristic of the Marcellus and lower Hamilton shales of New York. Other fossils observed in these beds are *Proetus sp., Paracyclas lirata, Tropidoleptus carinatus* (?), *Actinopteria decussata, Aviculopecten cf. insignis,* and other pelecypoda.

The highest exposed beds of Pine River Point contain *Stropheodonta nacrea* and *Spirifer mucronatus* in great abundance. Some layers are made up of the comminuted remains of crinoid stems. *Atrypa reticularis* is common, and other fossils observed are *Pentamerella dubia* (?), *Stropheodonta costata, Spirifer sp.,* Gomphoceras, and Cyrtoceras (?).

The extreme abundance of *Stropheodonta nacrea* and the constant association with it of *Spirifer mucronatus* suggests that we have here another outcrop of the *S. nacrea* beds of Loc. 40. As these beds are regarded as the lowest exposed in this region, probably not far overlying the blue shale (Bell Shale) of the well records, it is of interest to note the abundance of *Chonetes emmetensis,* which, like its eastern representative, *C. mucronatus,* appears to be an essentially lower Hamilton fossil.

A short distance farther west, in an old quarry, about 15 feet of shaly limestones are exposed. The shaly layers have their surfaces covered with fronds of *Stictopora incisurata,* and with this occurs *Chonetes emmetensis* in great abundance, some layers of the shale being covered with this shell. *Stropheodonta nacrea* and *Spirifer mucronatus* are abundant and

of the strata is 5 degrees to the south. The following succession has been determined:

A. The lowest exposed stratum has its upper surface about 5 feet above the water level. It is an argillaceous, shaly limestone, thin-bedded, and weathering a dark color. Near the top it contains specimens of Favosites, which were generally broken or worn before they became embedded in the rock. With them occur *Atrypa reticularis*. Thickness, 2 to 3′.

B. Compact, fine-grained dark limestone in beds varying from 2 to 6 or even 12 feet in thickness, and containing lenticular nodules of chert, the nodules sometimes nearly a foot thick: 3′.

C. Slaty limestones and slates, very fissile, in beds up to a foot in thickness, and separated by beds of banded chert 1 to 2 inches thick. Thickness about 5′.

D. From the point where the top of bed B dips below the water to the point where the top of bed D dips below the water, is about 300 feet. This, with a dip of 5 degrees, gives a thickness of about 26 feet for beds C and D, or of 21 feet for bed D. The top of the stratum shows beds whose surface are ripple-marked (oscillation ripples) and marked by sun-cracks. These beds are argillaceous limestones, readily effervescing in dilute HCl. Estimated thickness, 21′.

E. Shaly limestones similar to A, but more fossiliferous, containing *Spirifer* cf. *eatoni,* Cyathophyllum, Goniophora, and other fossils. Thickness, 5′.

F. Gray drusy dolomite, finely crystalline, and effervescing only on powdering, with strong HCl: 5′.

G. Darker dolomite, compact but crystalline, and containing fossils which are weathered out in relief and cavities from which pyrite concretions have weathered out. The cavities are stained by iron hydrate, and besides these there are numerous drusy cavities similar to those in F. Near the middle of bed G is a half-foot bed full of a small, undetermined cylindrical bryozoan. Stromatopora, Favosites, and a few other fossils also occur. Beds F and G are practically inseparable. Thickness, 4.5′. Total thickness, 45.5—46.5′.

These are the chert beds of Winchell, and Rominger describes these on page 60 of his report. Winchell gives 26 feet of strata; Rominger says about 25 feet. According to our measurements, which take account of the strong dip, the total thickness of these beds is fully 20 feet more.

Rominger gives the following analysis for the drusy dolomite of this section:

	Per cent.
$CaCO_3$	56.00
$MgCO_3$	39.00
Al_2O_3 and Fe_2O_3	2.8
SiO_2	0.4
	98.2

About half a mile south of the pier at Norwood the black[48] shales appear in low cliffs on the shore, gently dipping southward.

[48] It is this outcrop referred to by Winchell in 1860, p. 72, and even earlier in the first survey in 1841, H. D. No. 27, p. 108, by C. C. Douglass, which has led me, when informed by the U. S. Survey that the name St. Clair, which I had hitherto used, had been previously used in another sense, to apply the term Antrim to the shales lying above the Traverse, up to the Berea Grit, since they are well exposed here in Antrim county.—Lane.

THICKNESS OF THE TRAVERSE GROUP OF LITTLE TRAVERSE BAY.

In the Bay View well about 470 feet of limestones are shown above the blue clay. In the Petoskey well 325 feet are shown above the clay which is there found to be 80 feet thick. A 10 to 15 foot bed of blue clay was found at a depth of 250 feet below the surface of the limestone, or 75 feet above the blue clay at the base of the series. It is probable that this clay is the Acervularia clay, the well striking it at a point where fossils were scarce, since the record mentions no fossils. The thickness given is perhaps too great. Below this "a nearly solid bed of Acervularia limestone" was recorded. This appears to be the limestone exposed at the base of section 42, which often contains Acervularia.

In the Charlevoix well, as before stated, about 100 feet of the Petoskey limestone are exposed, below which the Acervularia clays occur, as shown by the perfect calices in the fragments of *A. davidsoni* and Favosites. Eighty feet below this, or about 110 feet below the first appearance of Acervularia in the well section, is the top of the blue shale. The record of the Charlevoix well is the most satisfactory, because the fragments from 5 to 10 feet intervals were carefully preserved. I shall consider the bed at 335 feet depth in the well, in which the fragments of Acervularia with perfect calices were found, as the Acervularia clay exposed in some of the sections. This would then give us a total of 110 feet for the lower strata below the Acervularia clay.

Putting together the records from the three wells, and from the exposures, we have the following succession and thickness of strata, which may be considered as a tentative summary of our knowledge of these beds:

	Feet.
Antrim black shale	
Chert beds	45–50
Petoskey limestone (the Stromatopora and the Buff Magnesian of Winchell)	360
Acervularia and *Stropheodonta nacrea* beds (Bryozoa beds of Winchell)	110
Basal shale (Bell shales)	80
Total	600

It thus appears that the thickness of the Traverse group throughout the northern portion of the southern peninsula of Michigan remains very nearly uniform. In the western region, mostly limestones were deposited, the shale being limited to the 80 feet basal layer, and to a few thin bands occurring at intervals. In the eastern area shale bands were more prominent, occurring at intervals in considerable thickness.

From our present limited knowledge of the faunas, correlation of the beds in opposite sides of the State is impossible. We may perhaps say that the Petoskey limestones and dolomites are, in general, the time equivalent of the Alpena limestone and the limestones of Thunder Bay Island. But beyond this little can be attempted in the way of correlation. The basal shale layer (Bell Shale) is of course an exception to this, for from its constant thickness it gives us a very clear and sharply-defined base for the Traverse group wherever it occurs in this portion of the lower peninsula.[49]

[49] It is also recognizable to the south.—L.

DEEP WELLS AND PROSPECTS FOR OIL AND GAS.

Every time of prosperity brings extra activity in explorations of all kinds. These in Michigan take largely the shape of drilling,—mainly with the diamond drill in the upper peninsula; with the churn drill in the lower.

Drilling for coal has not generally been over 400 feet deep; for salt it has varied from 800 to 2000 feet, while for oil it is liable to be any depth and not infrequently over 2000 feet. A perceptible fraction of my time has been occupied in studying samples and answering correspondence before, after and during the drilling of these wells. I have taken special pains in the collection of data regarding these wells, because if they are not collected at the time they are likely to be forever lost, and at my own expense have subscribed to the Michigan Press Clipping Bureau that none might be completed without my hearing about it. It has done good service, and I think should be continued from the appropriation.

In the fifth volume of our reports, Vol. V, Part II, p. 85, I called attention to the prospects for oil and gas, and the beds and areas most likely to contain them, according to the information available to me at that time. In that report, and the sections at the end certain anticlinals were somewhat vaguely indicated. The recently issued coal report gives one section which if correct would indicate an anticlinal beneath Saginaw and between Lansing and Owosso, and to these I have called attention in the public press. Dr. C. H. Gordon's report was received so late that it had to be relegated to the end of the report, and only this reference to it inserted here. It is an important paper, for besides the anticlinal somewhere north of Mount Clemens, which I refer to below, he has located an anticlinal close to Port Huron. As Prof. Russell has remarked to me such an extensive basin as that of Lower Michigan can hardly exist without minor corrugations especially around the margin, which ought to collect oil in valuable quantities. We may, for instance, from Grabau's paper just above, infer the probable existence of such a minor anticlinal near Khagashewung Point (Plate VIII), and from the records below one east of Niles and one near Stronach are rendered somewhat likely.

One thing is worth noting,—that wells which yield only a barrel a day or less, and are liable to be scorned by those whose eyes are filled with visions of gushers, may nevertheless be of value, if conveniently located and enough of them can readily be obtained.

In describing them it will be most convenient to use a partly local, partly topical arrangement, because in certain districts all the wells have one object. In others wells for different objects throw mutual light. Coal records have been very largely summarized already in my recent report.

In discussing the borings and prospects for gas and oil it has been convenient to consider a southwestern and a southeastern district, which really extends to Port Huron, though it may be convenient on some accounts to divide it into two parts. I have also considered separately the possibilities around Saginaw. The prospects for Alcona county are included in the report. Some recent explorations serve as an excuse for

describing some interesting wells in the upper peninsula. Finally I have made a few remarks about the northwest part of the lower peninsula at Muskegon and Manistee.

In studying explorations for oil and gas, one thing is apparent to the geologist—that the Neo-devonian black shales are responsible for most of the surface indications which start oil fevers and set people boring. It is also true that such indications have proved delusive. In fact, so far as surface indications in springs[1] are concerned, they indicate a leaky reservoir[2] if they indicate anything at all, and that is not a good sign for great accumulations below.

The same black shale is often mistaken for coal.[3]

It is true that deep wells into the drift, especially just above bed rock, will find quite frequently gas, and this may often pay for the well, for use in a house. But no great quantity can be expected, nor very long life.

Oily-smelling rock[4] at the surface, or gas or oil, have little value practically in this State in searching for oil. Almost all over the lower peninsula such strata can be found at some depth or other, and on the belt where the Devonian rocks lie beneath the drift, surface signs of oil may be expected.

SOUTHWESTERN DISTRICT.

It is not to be denied, however, that oil and gas-bearing strata exist beneath the southwestern point of the State,—both the Lower Devonian limestones, which yield the oil and gas around Petrolea, Canada, and the Trenton limestone, which is the famous oil rock of Ohio and Indiana. But the numerous wells drilled, and reported in Vol. V, at South Bend, Elkhart, Michigan City, Niles, Dowagiac, Constantine, Benton Harbor, Allegan and Kalamazoo, have not been successful in finding commercial quantities of gas. In spite of their failure, however, prospecting has not been entirely checked.[5]

It remains, therefore, to give a few facts regarding the new wells and new facts regarding those already reported on, and see what light they throw on the prospects for the future, the important thing being to see whether there is an upward flexure of the beds which might tend to collect the oil or gas.

---

[1] Kalamazoo Telegraph, 3:9, 1901, also 10:3. 1901.—Several wells in Lake township, Berrien county, strike gas in small quantities, and at Bridgeman a spring with a coating of oil was found by a planchette.
Niles Star, 6:14, 1900.—Gas at New Buffalo at 60 feet.
Grand Rapids Herald, 1:24, 1901.—Petroleum vein at cottage of Mrs. H. S. Cole, Benton Harbor.
See also Vol. V, Part II.

[2] I mean natural reservoir, though (Niles Sun, 12:11, 1900; Detroit Tribune, 12:13, 1900; Battle Creek Enquirer, 12:25, 1900; Detroit News-Tribune, 12:2, 1900; Detroit Journal, 12:22, 1900) at Buchanan oil leaking from Lee & Porter's tanks was taken to be natural.

[3] Three Rivers Tribune, 9:12, 1901.—Six-foot vein of coal at 150 feet near Benton Harbor.
Detroit Tribune, 6:6, 1901.—Coal at 550 feet. Compare record of well below.

[4] Benton Harbor Palladium, 1:23, 1901.

[5] Detroit Journal, 12:26, 1901.—Near Niles by B. F. Earl.
Detroit Today, 10:8, 1901.—Near Mendon by Darling Bros.
Allegan Chronicle, 4:77, 1901.—Valley Oil, Gas & Coal Co., near Allegan.
Grand Rapids Herald, 3:18, 1901; Allegan Gazette, 3:9, 1901.—R. W. Brown, at Allegan.
Benton Harbor News, 6:6, 1901, and 6:26, 1901; Detroit Tribune, 6:6, 1901.—Berrien Springs.
Niles Daily Star, 9:7, 1901.

An important recent well is one at Berrien Springs, an authentic record of which we owe to Hon. Roscoe D. Dix.[6]

	Record.		
Gravel	40	40	
Blue clay	70	110	
Soapstone	440	550	Reached 550 noon June 5. Compare Benton Harbor at 280 feet, Niles at 415 feet.
Black shale with pyrite, bituminous	70	620	Compare Benton Harbor at 475 feet, Niles at 460 feet. Dowagiac at 675 feet.
Limerock with indications of salt water at bottom	80	700	Stopped at 670 feet, June 15. Compare Dowagiac at 874 feet.

See also Grand Rapids Press, 7:9, 1901; Detroit Tribune, 6:6, 1901; Three Oaks Acorn, 7:12, 1901; Benton Harbor News, 6:6, 1901, and 6:26, 1901.

The striking feature of the Berrien Springs record is the depth at which the base of the black shale was found, greater than at Benton Harbor on one side or Niles on the other. This indicates a downward flexure of the strata.

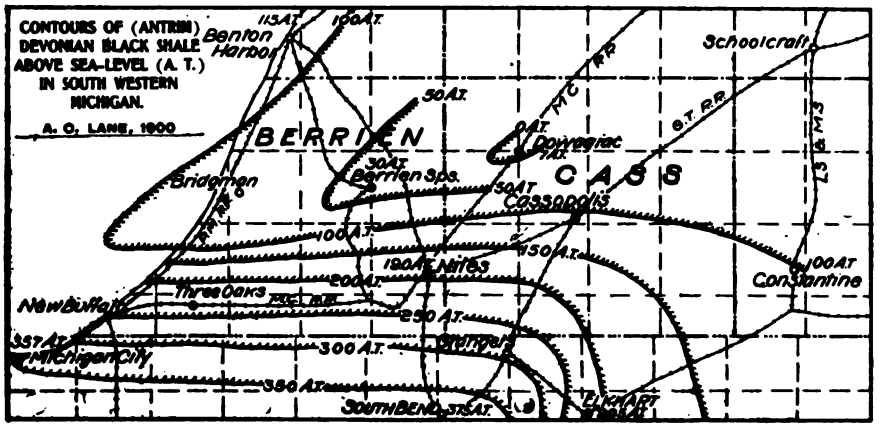


Fig. 4. Contours showing the elevation of the base of the Antrim (Devonian, New Albany) black shale, and the top of the Traverse (Hamilton) in Southeastern Michigan, above tide level, indicating an anticlinal pitching northeast, about 12 to 15 miles east of Niles.

The dip into the trough is also indicated by comparing with other wells as shown in the accompanying map. Fig. 4. While the strata all grow deeper to the northeast, there is a subordinate puckering or fluting, with a downturn between Niles[7] and Benton Harbor, and an upward turn

[6] Well 60 rods from north bank of St. Joseph river and about 50 feet, i. e., about 650 A. T.

[7] Five wells have already been put down in this neighborhood. Mr. F. W. Cook of the Daily Star and H. Gardner have helped me to gain information.

No. 1 was put down in 1865, close to the river and just below the bridge, was 500 to 700 feet deep, and yielding some gas.

No. 2. On Second street 20 rods this side of the railroad, yielding a large flow of water. One of the drillers told Mr. Cook that in driving for gas they met quite a little oil but were hired by the Standard Oil Co. to drive past anything of the sort. Drilled in 1885 to 1886.

No. 3. About same time (Plate XLIV of Vol. V), near C., C., C. & St. L. R. R., about 650 A. T.

No. 4. South of town one or two miles and on terrace 46 feet above river, i. e., probably above this. There was 70 feet 10-inch casing through clay, over 70 feet quicksand with water, 185 feet casing (or 280 says Dalton) to bed rock; then about 200 feet clay shale, toward bottom brown and bituminous, with petroleum smell; then limestone; at 546 feet strong brine, which rose to within 30 feet of the top, i. e., 15 feet above river. (Compare Berrien Springs at 700 feet, i. e., about 150 below tide.) Thereafter progress was but 3 to 6 feet per day to 580 feet. Cased with 5-inch casing, which was later recased to 880 feet to shut

between Niles and Elkhart. Consequently the more hopeful district to explore is east and southeast of Niles, say near Edwardsburg on the Grand Trunk, or Mendon, where oil boring is said to be progressing.[8]

There was a deep well drilled at Bangor, the record of which I have not been able to obtain,[9] which might be of interest as showing whether there was a marked upward bend on the other side of the Berrien Springs trough or not. The elevation of the base of the black shale at Allegan (387 A. T.) and Kalamazoo (over 423 A. T.) shows that as a whole the dip is to the northeast, but not at all inconsistent with such minor flexure.

SOUTHEASTERN DISTRICT.

Lying, as this district does, close to the Toledo fields and two large business centers, this district has received a disproportionate amount of attention. Prof. Sherzer has recently[10] described quite fully the wells of Monroe county, but the dips seem to be uniform from 29 to 32 feet to the mile to the northwest, and no pitching folds have been located. To the records previously reported in Vols. V and VIII we may add old wells at Blissfield and Ypsilanti, whose records have been recently obtained, and wells recently drilled at Ann Arbor, Milan, Britton and Riga.

YPSILANTI.

A number of wells have been put down here for sulphuretted brines, derived by a combination of the waters from the Berea grit and the Traverse and Dundee limestones. The original well was the Cornwall mineral well on the river flats, about 680 A. T., the record being:

out salt water, but got fresh water below, which rose as high as before. At 1000 feet they were told they had Trenton rock. (Compare rock at 1500 feet at Britton.) A little gas came in all the time, foaming up the water. At 1438 feet the well was abandoned. Dalton says his well was 1600 feet deep, and though higher than the down town wells seems to strike corresponding strata as soon. E. H. Crane of Colon is said to have a record.

No. 5 was but 200 feet or so from No. 4, across the river, and but 2 or 3 feet above the river level, i. e., about 636 A. T.

	Feet.
Clay, 10-inch casing	70.0
Water, sand and gravel	142.0
Eight-inch casing to bituminous shale as in No. 4.	
Casing 6-inch, shutting off water	503.3
Sand pocket, 6 inches salt water	504.0
15 feet from top, magnesian limestone	3.0
Gray limestone	6.4
Gray limestone	4.6

Then put down a packer and got some gas under salt water.
November 14, 1899.

What oil and gas appears in the wells is all from the Dundee or Canada horizon apparently, except that in Nos. 3 and 4 a little accumulation was noticed near the top of the Niagara. The Trenton was *not* reached.

[8] Detroit Today, 10:8, 1901. Darling Bros. heavy rock at 200 feet may also be on an upward bend.

[9] Except that it is 1260 to 1300 feet deep, is cased down 300 feet, and according to M. E. Haguire and C. B. Charles, flows a strong brine.

[10] Vol. VIII, Part I, Monroe County.

Pleistocene—		
Earth	8	
Clay	4	12
Gravel	18	30
Blue clay	4	34
Gravel	6	40
Fireclay	3	43
Hardpan gravel	5	48
Sand	32	80
Coarse gravel	9	89
Fine quicksand	20	109
Coldwater—		
Slate	241	350
Flint	5	355
Sandstone	38	393
Soft slate or sandstone	157	550
Bedrock (i. e., hard limestone) (?)	200	750

This is a very poor record. Of the Moorman well we have only the record of the casing. It is higher than the other (about 703 A. T.). At 125 to 150 feet there was fresh water. Down to 185 feet was the first casing to bed rock. At about 400 feet was the first flow, which was salter than the lower flow,[11] and was at one time cut off by a casing down to 550 feet.

At about 550 feet gas came in (H_2S), and the well continued down to about 965 feet.

The Atlantis well of T. C. Owen is about 80 feet higher, and the fresh water comes at 200 feet and the salt at 404 feet, directly under a very hard streak.

ANN ARBOR.

The old deep well at the court house, which is about 835 A. T., has already been reported by Winchell and Rominger. The following may be a provisional account of the new one,[12] which is about 875 feet A. T.

Pleistocene—			
Soil, find sand	45	45	Down 60, Sept. 14.
Large boulder at		80	
Gravelly, 10 ft. casing to	45	00	
Large boulder at		113	
Bluish clay	142	232	
To bedrock	3	235	Oct. 13.
Coldwater Shales—			
Bluish shales	30	265	Oct. 16.
Red shale	15	280	Oct. 17.
Plugged June 28 at 287 ft. and water above analyzed 4.3 per cent salts.			
Blue shale	75	355	to 375, Oct. 18.
Berea Shale—			
Black shale	30	385	to 400, Oct. 19.
Bluish shale	15	400	
Berea Grit—			
Sandstone	15	415	(No water noted).
Shale	60	475	to 425, Oct. 20; 465, Oct. 21; 475, Oct. 23.
Lighter shale with streaks of sand	85	560	to 505, Oct. 24; to 535, Oct. 25; to 570, Oct. 26; to 585, Oct. 31.
Salt water at		515	and below.

[11] See U. S. G. S. Water Supply Paper No. 31.

[12] Personal glance at samples. Record in Ann Arbor Daily Argus, Dec. 2, 1899; Jan. 5, Jan. 19, Feb. 16, Feb. 23; Ann Arbor Times, Feb. 15, June 28, July 1, July 6. Letters from Eberhard and notes from Prof. H. D. Campbell. Prof. Russell looked after the samples, and Mr. Frueauff of the Argus, at my request, took particular pains with the reporting.

Antrim Shales (Neodevonian)—

Black bituminous shale	20	560	
Black sand with white crystal	25	605	
Black bituminous shale	20	625	Nov. 3.
Black shale harder	48	673	
Black slate	27	700	680, Nov. 8.

Traverse Group (Meso devonian)—

Light slate	55	755	
Limestone (cherty)	15	770	
Limestone, very hard gritty and flint like (cherty)	35	805	
Black shale	45	850	
(Sample at 810 appears like a dolomite)			
Limestone, some gas indications	33	883	Nov. 15.

(Samples appear like the shale from 825 to 865, probably a blue argillaceous limestone such as is characteristic of this group.)

Light shale	47	930	
(Sample at 920 has note "struck hard.")			

Dundee (Corniferous) Limestone.

Limestone (at 960 feet struck a mineral water charged with H_2S which rose 300 feet and contained 13 per cent salts, according to Eberhard.[13])

November 18 operations were suspended for a month at the end of the first 1000 feet, in an oily dolomite or limestone. Between December 15 and December 28 work was resumed and remained the rest of the way in limestones or dolomites down to 1240 feet.

Monroe Beds—

There was a granular buff dolomite apparently at 1040 feet. On January 5 at 1065 feet a red rock with much iron was struck. From January 12 to January 19 the hole was reamed out and the 6½-inch casing carried down from 1000 feet to 1150 feet, shutting out the water. At 1235 feet the rock appears like a very fine-grained dolomite.

Total limestones and dolomites	310	1240

Sylvania sandstone—

Samples below 1240 are a fine (.1½ mm.) quartz sand as far as they are taken, 1270 feet. According to the newspapers at 1275 feet on February 10 another mineral water strong of H_2S with 17 per cent salts (Eberhard) was struck in limerock, in which a progress of but 7 or 8 feet per hour was made. The driller evidently did not report or recognize the sandstone, which may continue. By Wright it was taken as Oriskany.

At 1300 feet the rock is said to have been a little softer. The well was shut down February 26 at 1326 feet. It was then plugged at 283 feet and tested. Then a cement plug of 25 feet was put on top, but the analysis remained practically the same, to wit:

Specific gravity	1.039 or 1.0588
SiO_2	.0235 or .032 or .027
$(Fe\ Al_2)O_3$	.0305
CaO	1.040 or .885
MgO	.295
SO_3	.0245
Cl	3.20
Total S (H_2S in Sol)	.35
CO_2	
No K, Br, or I	

It will be seen by comparing the wells with those at Ypsilanti that the dip continues fairly steady to the northwest. This will also appear from the Milan well.

That the dip continues appears also by comparing the Sylvania sandstone with its position in wells near the Detroit river, for instance those given below.

[13] Campbell says the water analyzed was at 930 feet.

Specific gravity	1.094
$CaCl_2$	2.3975
$CaSO_4$	1.6331
$MgCl_2$	1.2336
K Cl	trace
NaCl	7.4163
Sr	?
I	.....
Total	12.8705
Directly determined	12.89

Saturated with H_2S.

This is a characteristic water of the Dundee or Corniferous limestone.

J. B. Ford (Michigan Alkali Company), Wyandotte. The "limestone" is generally dolomite, sometimes anhydrite.

	No. 1.	No. 4.	
Soil (surface)	to 63	60	
Limestone	282	195	
Sylvania sandstone	372	375 435	to 460 "soapstone"
Limestone	830	783	
Salt	876	1100	
Limestone	968		
Salt	976		
Limestone	984		
Salt	993		
Limestone	1126		
Salt	1213		
Limestone	1223		
Salt	1300		

Stroh's brewery in Detroit, on Gratiot avenue, is geologically higher and the well is said to have gone through:

Blue clay	110	110
Hard pan	30	140
Boulders	14	154
Traverse group	164	300
Dundee limestone with sulphur water in Monroe beds to	615	
Sylvania sandstone	85	700
The lime rock hard at 730, sandy at 800, and hard pan 900 to 1150.		
Salt	55	1205
Limestone	201	1406
Salt	24	1430
Limestone	135	1565
Salt	250	1815
Limestone	282	2097

The Wyandotte well, reported in Vol. V, reached the Trenton at 2610 feet. To the south the Sylvania sandstone rises, outcropping, as we have said, in Monroe county, and at Trenton we have for one of the six Church wells:

Dundee—

Light brown limestone	75–140
Softer light brown limestone	150–220

Monroe—

Dark brown dolomite	230–280

Sylvania—

White sandstone	290–400
Band of dolomite	410–420
Calcareous sandstone	420–470
Dolomite with much white chert	480–490
Shaley in streaks	500–590
	600–680
Gypsiferous dolomite, passing into	690–710
Bluish gray gypsum shales	720–840
Very rich in gypsum	850–880
Gypsum bed, the gypsum is really anhydrite	880–890
Dolomite	890–900
Gypsum	910–930
Dolomite, light yellow	940–950
Dolomite bluish and buff	960–980
Dolomite, light buff with some bluish	990–1000
Bluish gray gypsiferous shale	1010–1090
Deeper blue shale, (gypsiferous 1000–1185)	1100–1190
More largely cream colored dolomite (salt in some wells)	1190–1240
Largely bluish gypsiferous shales	1240–1290
Bluish passing into brownish dolomites	1290–1340
Brown dolomite with a smell of gas	1340–1370

To the north wells are very numerous. We cannot here give all the Solvay wells. They must be left for a special report. The Sylvania sandstone occurs in No. 6 from 410 to 490 feet, and in No. 10 from 420 to 523 feet, while the first salt begins in the one case at 873 feet, in the other at 891 feet.

Between them and the Wyandotte wells near the River Rouge, Mr. Dalton put down wells for the Tecumseh Salt Company in which, under dolomite, with heavy flows of sulphuretted water, the Sylvania sandstone was found from 365 to 492 feet, and the salt also came a little higher—at 828. This is higher than it is north or even than across the river, as shown in the Windsor well given below, but the pitch to the west is strong. The Detroit Salt Company got salt from 906 feet on. At the Brownlee well the salt comes in at 875 feet.

A little farther down river toward Wyandotte the River Rouge Improvement Co. put down a well for the United Alkali Co., the record of which is as follows, with notes from samples, which the survey owes to the kindness of Mr. H. M. Campbell:

Clay	80	80
Gray lime (dolomite)	270	350
White sand (cleanrounded glass sand, Sylvania	100	450
Dark sand (with chert and dolomite)	50	500
Lime (blue dolomite)	315	815
Salt	52	867
Lime (buff dolomite)	30	897
Salt	23	920
Lime (dolomite with acicular cavities)	25	945
Salt	15	960
Lime (buff dolomite)	35	995
Salt	70	1065
Lime (blue and buff dolomite)	95	1160
Gray lime	20	1180
Salt	20	1200
Salty shale and lime (anhydrite?, bluish, dolomitic)	125	1325
Salt	120	1445
Salt shale	15	1460
Salt	78	1538
Lime (dolomite)	35	1573
Sand (granular dolomite) last two total 62?	30	1603

WINDSOR.

Canadian Pacific Railroad. Well No. 11.

Dolomite, hard, white	to	235
" " fawn		250
" marly drab		275
" " "		300
Limestone, dark color, petroliferous		325
Dolomite marly		335
" " drab		365
" " grey		390
" vesicular drab		410
Limestone		440
Dolomite, crystalline fawn		460
Limestone, drab		490
" "		535
Sandstone, quartzose (Sylvania)		590
Dolomite, fawn		600
" with Gypsum, grey		640
" shaly, drab, somewhat arenaceous		670
" drab grey		700–760
" fawn		800
" hard, drab grey		825
" shaly, grey		840
" fawn		880
" drab grey		925
" " "		960
" fawn grey		1030
" drab grey with gypsum		1070
" shaly, drab grey		1100
" drab grey		1127
Salt		1167

28 February, 1894,
H. P. Grunnell.

RIGA.

A well was put down here some two years ago, but owing to a dispute and legal proceedings the only record I can give is that from 1165 to 1275 feet the samples appear to be in the white dolomites of the Niagara, such as occur from 1570 feet down to the bottom of the Britton hole, and this is the depth at which they would be expected.

BLISSFIELD.

On Sec. 30, T. 7 S., R. 5 E., is a well costing $5,000 and 2402 feet deep, down to the Trenton. Only a meager record from memory could be obtained, which we owe to Horace Wood. It agrees fairly well with a 35-foot to the mile dip from Toledo to Adrian, i. e., there is no sign of a fold.

Drift	100	100
Gravel; water rose and filled first 8 inch casing	20	120
First limestone about (to (?) dark slate and black water)	300	420
Water in limerock at		1600
Struck Trenton at		2342
Trenton rock	60	2402

MILAN.

A few rods south of the line between Washtenaw and Monroe counties, a well has recently been drilled. A record and samples were kept by A. E. Putnam, and I made two flying visits during the progress of the well. The record may be summarized thus. The well is about 685 feet A. T.:

Pleistocene—		
Surface (drift, clay, quicksand about 60 feet, and clay)	130	130
Traverse—		
Cherty limestone	30	160
Blue shale	45	205
Blue shaly limestone	65	270
Limestone (fissure?)	28	298

The top of the Dundee cannot be clearly made out owing to the caving. It is surely somewhere between 165 and 298 feet, more probably at or near the latter figure.

Dundee—		
Limestone quite fine, H_2S water (brecciated and caving)	97	395
Monroe—		
Dolomite acicular, caving to 425 feet	30	425
" sandy	10	435
" with gypsum	20	455
Gypsum, mainly	80	535
Sylvania—		
Sandstones, pebbly at 820	288	823
Various veins of water, calcareous shale	7	830
Dark oily dolomite, more sulphuretted water	15	845
Cherty dolomite	55	890

BRITTON.

Here a well was recently put down at the remarkably low price of a dollar a foot for 1700 feet. Comparing with Milan, we find corresponding samples from 100 to 150 feet deeper. The top of the well is only about 20 feet higher, and the record is:

Pleistocene—		
Surface clay and gravel	93	93
Neodevonian (Antrim)—		
Black shales	67	160
Pyritiferous grey shale	15	175
" black shale	35	210
Traverse Group—		
Cherty dolomite	25	235
Green shale	30	265
Cherty dolomite	40	305
Blue calcareous shale	95	400
Dundee (Corniferous) Limestone—		
White or brownish crinoidal limestone with water and traces of oil and gas	100	500
Monroe		
Gypsiferous dolomite	75	575
Gypsum	50	625
Dolomite	50	675
Dolomitic limestone	33	708
Dark cherty dolomite	37	745
The same, bluer	5	750
Sylvania—		
Dolomitic sandstone	25	775
Gypsiferous dolomites	50	825
The same with a little chert and sand	75	900
Dolomitic sandstone	100	1000
Salt water		
Shale	15	1015
Casing to 1012 or 1015 feet.		
Dolomite, dark blue at 1180 feet	585	1500
Rope black, and H_2S at 1200, where there is a slow very salt seepage. There is said to be 30 feet of brown oily dolomite at 1400 feet. (?)		
Dark brown oily dolomite	50	1550
Niagara—		
Light white sugary dolomite typical Guelph[14]	84	1643
Mineral water[15] at		1600

CaCl	20.507
$MgCl_2$	6.516
$MgSo_4$	1.685
Insoluble	.114
NaCl	39.452
	68.274

The balance being water of crystallization mainly. This is not as strong as a Dundee or Salina water would be at this depth.

At 1617 feet the thermometer stood at 63 degrees F.; at 945, 50 degrees F.

The water from the last bailing was at 52½ degrees F.

The water at the bottom is probably not as salt as above at 1200 feet, and there is some circulation going on.

[14] Small residue of quartz, rounded or not, with minute particles of microcline, hornblende, magnetite, etc., usually about 0.2 mm. in diameter.

[15] Specific gravity, 1.059; 90.648 grains per litre by evaporation. Partial analyses by F. S. Kedzie.

PORT HURON DISTRICT.

It appears from the wells just quoted, and those already given in Vol. V of Adrian, Pontiac, Royal Oak, Mt. Clemens, etc., that through most of Monroe, Lenawee, Wayne and Washtenaw counties the beds dip quite steadily, at a rate of 30 feet to the mile or more, somewhat west of northwest. When we go on from Mt. Clemens we find that the strike suddenly veers from north of northeast to due east, as is clearly shown by comparing the well at New Baltimore with those at Mt. Clemens and Marine City.

The region north of Mt. Clemens is therefore much more favorable for oil explorations. (See Plate IX.)

This is the only district in the State where there is a commercial production of oil, a refinery being conducted at Port Huron by Mr. George B. Stock. It seemed, therefore, wise to me to engage Prof. C. H. Gordon, who prepared our report on Sanilac county, to make a special study of the wells around Port Huron for oil and gas. These do not go to a depth of over 800 feet. He finds some indications of an anticlinal near Port Huron, but his report has not been received in time for insertion here; it will be found at the very end of the annual report. Besides these wells, a great many of which have already been published in Vol. V, there are a large number along the St. Clair river, Lake St. Clair and Detroit, which have been put down deeper for salt. The new well at New Baltimore, with a fine set of samples, is an important connecting link. We have also a very good set from the Diamond Crystal Salt Company at St. Clair.

NEW BALTIMORE.

The record of the New Baltimore well, put down by J. J. Mason & Co. for C. M. Swift, is as follows:

NEW BALTIMORE.

Name.	Thick.	Depth.	Comparisons.
Pleistocene—			
Surface	120	120	
Neodevonian Shale—			
Blue shale	5	125	
Black shale	335	460	St. Clair, 400; Marine City, 460: Pontiac, 965; Mt. Clemens, 218.
Traverse—			
Limestone and calcareous shales	20	480	
Limestone	50	530	St. Clair, 630; Pontiac, 1065.
Blue shale	160	690	St. Clair, 790; Algonac, 513; Marine City, 740 to 635; Pontiac, 1235; Mt. Clemens, 400.
Dundee—			
Limestone high grade	130	820	St. Clair, 910; Marine City, 825 to 770; Mt. Clemens, 610.

Monroe Group—			
Dolomites including	290	1110	Marine City, 1060.
Gypsum bed (anhydrite)	10	870	St. Clair, 990.
Gypsum bed	10	895	
Brown dolomite	20	940	
Limestones	165	1275	St. Clair, 1380; Marine City, 1220.
Brown dolomite and gypsum	85	1360	
Blue dolomite, shale and gypsum	35	1395	St. Clair, 1480; Marine City, 1390.
Buff dolomite	50	1445	
Blue and brown dolomites and gypsum	155	1600	St. Clair, 1600; Marine City, 1604.
Salt	40	1640	

The Diamond Crystal Salt Company at St. Clair have recently furnished a careful set of samples, from which a record may be made as follows:

SAINT CLAIR.

Name.	Thick.	Depth.	Comparisons.
Pleistocene—			
Surface	172	172	
Neodevonian—			
Blue shale (Erie)	110	310	
Black shale (Huron)	220	530	Marysville, XL, 298; Marine City, XXXIV, 360; Oakland, LXII 840; New Baltimore, 400-460.
Traverse—			
Blue argillaceous limestones and dolomites, etc.	100	630	
Blue shale	160	790	Marysville, XL, 588; Marine City, XXXIV, 630; Oakland, LXII, 800; Mich. Salt No. 2, 575; New Baltimore, 695.
Dundee—			
Limestone	120	910	New Baltimore, 820.
Monroe—			
Dolomites	80	990	Marine City, XXXIV, 800 ft.
Gypsum and dolomite	40	1030	Marysville, XL, 345; New Baltimore, 860-920; Oakland, 1000-1250 and other mineral wells water here.
Dolomite probably sandy about	1270		
Offset through Sylvania sandstone	240	1370	New Baltimore, 1370.
Dolomite	80	1450	
Anhydrite largely	50	1500	
Dolomite	40	1540	
Dolomite	70	1610	New Baltimore, 1600; Marine City, 1577-1633; No. 3, 1668; LXI, 1630.
Salt and cavity	30	1640	
Lime, i. e	10	1650	
Dolomite and anhydrite	97	1747	
Salt	50	1797	
Lime (?)	10	1807	

It seems clear that corresponding beds are 100 feet or so deeper than at New Baltimore, nearly 200 feet deeper than at Marine City,[16] and, what is especially remarkable, deeper than at Marysville or Port Huron.

[16] The following is a record of a recent well furnished by S. C. McLouth, in which the top of the Dundee is at 575 feet, instead of 635 feet as in Plate XXXIII of Vol. V.

Well No. 2. Commenced to drill June 7, 1898. Finished August 29, 1898. Pipe in September 2. Pumping well September 4.

Clay to 150 feet, 15 feet hardpan, clay and gravel to 200. Two hundred feet of black slate, 15 feet of lime. (Put in 218 feet 10-inch pipe to shut off surface. From 200 to 1400 is 8¼ hole.) 50 feet soft white soapstone, hard to mix. Could cut about 4 feet per hour with a 4-inch stem 43 feet long. Rock became darker and a little harder to 575 feet. Struck limestone, then we strung a 5¼ stem 38 feet long. The average then was 2 feet per hour to 710 feet. We struck sulphur water, 725 feet salt water, 730 feet brownish limestone, soft. Continues limestone easy on bits to 780 to 795, a streak of gypsum. 800 feet hard streak of lime. 825 feet gypsum. 830 feet hard. 850 to 860 gypsum, bothered. 870 hard streak of lime. 875 soft blue gypsum. 900 shelly limestone to 970 feet, average 15 inches per hour from 970 to 1000. Flint limestone from 1000 to 1040 feet. Good drilling, 18 feet in 12 hours. Continues the same kind of rock to 1100 to 1160. Sandy limestone. Hard. Continues awful hard. 8 inches per hour from 1160 to 1225. Hard to 1300, bothered with caving rock and gypsum. Gypsum in limestone to 1370. No trace of gypsum from 1370 to 1400. Cased at 1400, 6¼-inch casing. Awful hard to 1500. Continues hard to 1570, where we struck salt. 25 feet salt in the first bed, 10 feet lime and 10 feet salt to 1605. Lime to 1612. Lime 11 feet. Top salt bed 1623 feet. Lime 1751, total depth of hole.

We find here, therefore, irregularities of dip such as are favorable to the collection of oil. If we are right in our correlations of the Algonac and Port Lambton wells in Vol. V, here, too, there is a corresponding drop,—from Algonac to Port Lambton, the top of the Dundee dropping from 513 to 710 feet. About 10 miles southeast of Port Lambton in Canada, at Wallaceburg, a well was sunk in 1899, the record of which I owe to the kindness of Mr. Ami,[17] and it will be well to repeat it here with my correlations.

WALLACEBURG.

Name.	Thick.	Depth.	Comparisons.
Pleistocene—			
Sands and clays	35	35	
Boulder clay	85	120	
Shale	180	300	
Limestones	75	375	
Shale and sandstone	74	449	cf. Marine City, XXXV, 370-480 ft.
Traverse—			
Limestone, "top limestone"	106	555	
Shale, "top soapstone"	95	650	" 600 ft.
Limestone, "middle limestone"	15	665	" 640 ft.
Shale, limestone and clay	85	750	" 730.
Dundee or Corniferous. (Top of Monroe not separated)—			
Light colored limestone. Perhaps the lower part is dolomite.	250	1000	
Sylvania—			
Sandstone[18]	100	1100	
Fine grained dolomites	290	1380	
Gypsiferous " (No salt reported, the record may be imperfect.)	320	1700	
Niagara—			
Dolomites	120	1820	
Limestone. Oil at 1865.	105	1925	
Calcareous and arenaceous shales	110	2035	
Medina—			
Gray sandstone, Red shale and marls	65 +	2100 +	

It seems that even at Wallaceburg the top of the Corniferous or Dundee is not quite as high as it is at Marine City, and lower than at New Baltimore. The indications for an anticlinal or some other disturbance which might collect oil and gas in large quantities between Mt. Clemens and St. Clair and northward are not bad. The anticline which Dr. Gordon finds trace of lies even nearer Port Huron. See his paper at the end and Plate IX.

SAGINAW.

The structure of the rocks of lower Michigan is basin-like. This is shown by such cross sections of lower Michigan as are given, for instance, in Vol. V of our reports. This structure is not favorable for the gathering together of large and valuable deposits of oil and gas. For oil and gas are formed by the slow decomposition of animal and vegetable matter which was buried with the rocks in the bottom of the sea when they were formed. If now there is an upward bend or dome of the strata, known technically as an anticlinal, covered over by impervious beds, such as

[17] Jour. Can. Min. Inst., Vol. II, pp. 186-191. Ottawa.
[18] Suggested as Oriskany by Mr. Ami.

clays or shales, the oil or gas may collect in large quantities in porous beds or fissures beneath. Otherwise they are likely to be scattered in too small quantities to be of much value.

It is easy to see that a basin structure will tend to produce scattering rather than an aggregation.

There are, however, two possible exceptions.

Around the margin of the basin there may be radial flutings like those around the edge of some cake-tins, and in the upward bends of these oil may accumulate. For instance, the strata which run northeast past Detroit through Monroe and Wayne counties, turn in Macomb and St. Clair counties and run almost east. Thus from Macomb county toward the center of the basin (north or west) somewhere there must run the top of a bend which might accumulate larger quantities of oil.

Again, near the center of the basin, minor upward flexures or flutings may occur, which would serve to collect the gas.

Now there have been a very large number of wells put down along the Saginaw river, and from them we may infer that the crest of an anticlinal or upward fluting crosses the Saginaw river in the city of Saginaw not far from the Wylie Brothers' wells.

This is shown in Plate IX of Vol. VIII, Part II,—the report on coal by A. C. Lane.

For we have:

At the northern part of Bay City, Marshall sandstone from 830 to 920 feet down. General depth of brine wells, 1050 feet.

South part of Bay City, Marshall from 840 to 970 feet.

Wells at Melbourne are about 890 feet deep. At East Saginaw the first well in the north part struck Marshall sandstone at 633 to 742 feet, and the same sandstone comes in Gov. Bliss' well across the river in Zilwaukee at 665 feet, and two miles north in the New York and Saginaw Salt and Lumber Company's well, it is from 760 to 867 feet deep. Going south, however, the salt rock, i. e. the sand rock is said to rise, and at Wylie Brothers' well it is said to be but 715 feet through the salt rock. Beyond this, however, the salt rock deepens again; in South Saginaw, where it is 715 feet to the top of the sand rock; at Garfield, where the salt well was over 800 feet deep, and at St. Charles, where the new salt wells are between 800 and 900 feet deep.

Inasmuch as the wells at Midland, Alma and St. Louis find the Marshall sandstone at 1000 to 1200 feet, it is there much deeper. The upper bend indicated by the wells along the river may be a fluting pitching to the west.

If the oil and gas-yielding strata conform to the Marshall, however, the region of Wylie Brothers' well might contain oil or gas in commercial quantities.

The first stratum of importance in this connection below the Marshall is the Berea grit. This showed strong signs of oil and gas at 2080 feet in the well at South Bay City, the record of which is as follows:[19]

Pleistocene—			
Surface (made land and slabs)	10	10	Began Dec. 30, 1896.
Clay, thin seams of sand	40	50	
Sand	5	55	
Clay	15	70	
Sand (black at 92 feet)	30	100	
Clay	5	105	

[19] The dates give some indications of hardness.

EXPLANATIONS

(Nearly equivalent names on maps.)

FORMATIONS.

ARCHEAN—*Precambrian*

Laurentian, *Basement complex*, and granitic rocks: Gr serpentine; gold, and other veins.

Huronian, *Lower Algonkian*, iron-bearing rocks. Iron graphite, slate, jasperite, etc.

Lower Keweenawan, *Copper-bearing* rocks: native c nickel and copper ore, porphyry, melaphyre and con ente, coal metal.

Line between Cambrian and Archean uncertain

Upper Keweenawan and Lake Superior Sandstone

Potsdam: Basement and sandstone

SILURIAN

Calciferous, *Lower Magnesian* and *St. Peters*. Sandy mites.

Trenton, including also Birdseye and Chazy: Dolomi limestone somewhat oil-bearing.

Lorraine and Utica, *Hudson* and *Cincinnati*. Blu black shales, with some limestone.

Niagara, including *Guelph* and probably *Clinton* dolomites and limestone, gas (?)

Monroe, including *Waterlime*, *Salina*, *Onondaga* nites with rock salt, gypsum, glass-sand, strontian erals, brines and mineral waters.

In Monroe County the full line indicates the co the Sylvania sandstones, the dotted line a bed of oölitic

DEVONIAN

Dundee, *Carniferous*, *Upper Helderberg*. Mineral phur) water, oil and gas signs, limestone for chemica

Traverse, *Hamilton* and *Marcellus*. Some pure limes reefs, some dolomite, much blue argillaceous lim shales, cement material, oil and gas signs.

Antrim, *Ohio*, *New Albany*, *Genesee*, *Portage* and *Ch* Mainly black shale, often bituminous and cause of valu for coal, oil and gas.

CARBONIFEROUS

Berea Grit, marked by line between Coldwater and Sandstone, good brines, and signs of oil and gas.

Coldwater, *Waverly* and *Berea*, *Cuyahoga*. Shale able for Portland cement and brick.

Marshall, *Kinderhook* (?), *Lagrus*. Fresh water, bri bromine, sandstone and grisdstone.

Grand Rapids, *Maxville*, *St. Louis* above, *Augusta lut* (?) below. Limestone above, gypsum, shales draulic limestone below

Saginaw formation—*Pottsville*, *Millstone Grit*: C ing brick, clays and shales, sandstone, etc

Coal Measures—			
Shale	33	138	
Quicksand (probably fissure)	2	140	
Sandstone, 165 on Jan. 5, salt at 220, oily at 280	138	278	
Shales black and white and sandy	122	480	
Thin seam of coal at		480	
Pyrites (top of sandstone)	10	490	
Parma—			
Sandstone	50	540	
Eocarboniferous,			
Upper Grand Rapids. (Maxville)—			
Limestone	70	610	
Sandstone	10	620	
Lower Grand Rapids—			
Limestone	5	625	
Shale	25	650	
Gypsum, etc	10	660	
Limestone 10 ft., shale 10 ft., sandstone 10 ft.	30	690	
Gypsum 15 ft., limestone 5 ft., gypsum and shale 10 ft.	30	720	
Shale and sandstone	60	780	
Limestone	10	790	
Limestone, gypsum and shale	10	800	
Limestone and shale	20	820	
Shaly limestone and pyrites	20	840	
Upper Marshall or Napoleon—			
Sandstone and salt water	130	970	Feb. 2, 1899.
Lower Marshall—			
1000 ft. Feb. 4, 1040 ft. Feb. 6.			
Red sandstone	90	1060	
Blue shale	30	1090	
Red shale	20	1110	
Red sandstone	20	1130	
White shale	50	1180	
Red and white shale	5	1185	
1210 ft. Feb. 8.			
Red sandstone	105	1290	
Coldwater. (Cuyahoga)—			
Light white shale	620	1910	
1310 ft., Feb. 9; 1380 ft., Feb. 10; 1580, Feb. 14; 1660, Feb. 15; 1750, Feb. 16; 1840, Feb. 17; 1900, Feb. 18.			
Red and blue shale	30	1940	
1990 ft. Feb. 19; 2000 ft. Feb. 20	10	1950	
Blue and white shale	100	2050	
Berea Shale—			
Red and white shale	10	2060	
Black bituminous shale with signs of oil and gas	30	2090	
2070 ft. Feb. 21, 2110 Feb. 22.			
Berea Grit—			
Grey sand rock,			
2140 ft. Feb. 24; 2170 ft. Feb. 25; 2210 March 1	10	2100	
White sandrock, strong brine, analyzed[10], flowing over the surface	160	2265	
2230 ft. March 3; 2244, March 4; 2250, March 6; 2265, March 9; 2270, March 10.			
Neodevonian (Antrim Shales)—			
Blue shale (Bedford)?	25	2290	
Black shale, oily with gas	14	2304	
Rock salt (?) March 13	6	2310	
2315, March 14; 2350, March 22; 2360, March 23.			
Black shale only	60	2370	
2370, March 24; 2380, March 25.			
Black shale, signs of limestone	10	2380	
2400 ft., March 29; 2410, March 31; 2420, Apr. 1; 2430, Apr. 4; 2440, Apr. 5; 2450, Apr. 6; 2460, Apr. 8; 2470, Apr. 10; 2480, Apr. 12.			
Black calcareous shale	110	2490	Apr. 16.
2500, Apr. 19; 2510, Apr. 24; 2520, Apr. 25; 2540, June 19; 2550, June 24; 2560, June 27.			
Black shale, hard, with pyrite and signs of oil and gas	90	2580	June 28.

[10] U. S. G. S. Water supply paper No. 31.

Mesodevonian (Traverse Group)—			
Limestone and shale	30	2610	June 30.
2620, July 1.			
"Limestone" dolomite	20	2630	July 3.
"Sandstone" dolomite	10	2640	July 5.
Sandy limestone	10	2650	July 6.
2660, July 7; 2690, July 8			
Blue shale	50	2700	
2715, July 10; 2730, July 11.			
Limestone, mixed	16	2716	
Shale	18	2734	
Sandy limestone with gypsum	6	2740	July 12.
2750, July 13.			
Dolomite like bottom of Alma well with gas and brine	20	2760	July 14.
(Canadian oil horizon). Some H_2S.			
2770, July 15; 2780, July 17; 2790, July 19; 2800, July 20; 2810, July 21; rope broke,—2818, Nov. 10; 2828, Nov. 11; 2838, Nov. 12; 2860, Dec. 2; 2905, Dec. 5; 2912, Dec. 7; 2925, Dec. 9.			
Limestone, yellow hard like Corniferous, compare Alpena limestone	180	2840	Dec. 11.
2960, Dec. 13; 3020, Dec. 14; 3060, Dec. 15; 3100, Dec. 16.			
Blue shale (slate)	180	3120	Dec. 17.
Blue limestone and gypsum	40	3160	Dec. 18.
Blue limestone, shale and gypsum	20	3180	
Limestone and shale, slightly browner	10	3190	Dec. 19.
Black shale and limestone	60	3250	Dec. 20.
Dark brown limerock, shale and gypsum	20	3270	Dec. 21.
Dundee or Corniferous—			
3280, Dec. 28; 3290, Dec. 30; 3300, Dec. 31.			
Limerock	40	3310	Jan. 1, 1900.
Lighter limerock and white sand	20	3330	Jan. 2.
3340, Jan. 3; 3370, Jan. 24; 3380, Jan. 5; 3390, Jan. 6; 3410, Jan. 7; 3420, Jan. 8; 3450, Jan. 9.			
Light limerock	130	3460	Jan. 11.
3470, Jan. 12.			
Limerock and sand	20	3480	Jan. 14.
3490, Jan. 15; 3500 Jan. 16.			
Limerock	28	3508	Jan. 18, 1900.

It will be noticed from the above that the signs of oil and gas occur from the base of the Berea shale down, and this is 1120 feet below the base of the Napoleon sandstone, which is the main salt rock. If we suppose this at Wylie Brothers' well to be but 715 feet down, then the beds most likely to yield oil or gas, the next 500 feet below the top of the Berea Grit, will be from 1825 to 2325 feet down at Saginaw, and there would be two or three brines to be encountered. Next would come a rock salt and dolomite formation for 1000 or 1500 feet more, perhaps. Then comes the Niagara for 400 to 800 feet, which has occasionally yielded oil and gas. Before we reach the Trenton oil horizon, which has a great reputation among oil drillers, there will be possibly 600 feet more of shale, red, blue and black. This is the lowest oil horizon of which we have any knowledge, and it would take a well 5000 feet deep to explore it.

But in regard to any of these horizons there is a good deal of uncertainty. The Berea Grit is not always present. It may not conform in such a matter as slight undulations of a hundred feet or so to the Marshall, and it may not be porous enough to yield gas in considerable quantity. As in most underground operations, there are large prospects of failure, with proportionate rewards in case of success.

The Trenton and Niagara are so deep that the cost of exploration bears no ratio to the chance of success. But the Berea Grit is at a reasonable depth and a glance at the dates given with the Bay City record shows that the drilling between it and the Napoleon rock is easy, only three weeks' work or so. In case oil or gas was not encountered, the brine might be of value.

NORTHERN PART OF THE STATE.

The prospects around Alpena county have already been referred to.

Recent wells on St. Joseph's Island just over in Canada, Neebish, St. Ignace, Cheboygan and Grayling, put down for salt or oil, give material for a pretty good section from north to south, and seem to indicate but little prospect for oil or gas. The only qualification that need, perhaps, be made is that near the possible outcrop of the Berea, that is along a line from Harrisville to Atlanta[21] and Vanderbilt, and thence southwest there is the same possibility of moderate accumulations. The records of the wells referred to are as follows:

On St. Joseph's Island a well 200 feet deep is said to have struck the Huronian without striking oil, but we have no farther details.

NEEBISH ISLAND.

On Neebish Island near Sailors' Encampment, T. 45 N., R. 2 E., only a few feet from and above the water, a well was put down by A. W. Palmer for the American Alkali Company to a depth of over 527 feet[22] with the following results:

No samples, drift?	111	111
Trenton—		
Argillaceous limestone	5	116
Light fossiliferous limestone	12	128
Light dolomitic "	10	138
Bluish " "	10	148
Light " "	10	158
Chazy (?)—		
Thin bluish dolomitic limestone	5	163
Light bluish limestone	48	211
Calciferous (?)—		
Sandy dolomite	3	214
Mixed drillings	4	218
Dark slaty	5	223
Potsdam, Upper—		
Clean white sandstone, a glass sand, like that on the north part of Sugar Island	161	384
Light red sandstone	33	417
Potsdam, Lower (Lake Superior Sandstone)—		
Coarse red sandstone, conglomeratic with pebbles of red Huronian quartzite	110	527 to 565?

According to Rominger's description the location of this well should be close to the top of the Trenton, and I think it likely. The divisions of Chazy and Calciferous are lithologic and very uncertain.

ST. IGNACE NO. 2.

The new well at St. Ignace is about two miles north of the old well on Sec. 31, T. 41 N., R. 1 E., about 600 feet north of the town line, 300 feet from Lake Huron, 590 A. T. or less.

[21] Near which, on Sec. 7, T. 30 N., R. 3 E., is a spring that yields gas like those near Killmaster.

[22] Five hundred sixty-five feet says the Michigan Miner, December, 1901, p. 16.

Comparing with the first well reported in Vol. V, it appears that the beds dip about 40 feet per mile to the south. The record is:

Pleistocene—		
Surface	34	34
Gravel with gypsum	9	45
Monroe—		
Dolomite	63 to 89	
Dark dolomite	100 to 104	
Gypsum	174 to 187	
Red shale		
Blue shale		
Gypsum	255 to 260	
Red shale		
Blue shale		
Gypsum, about	300	
Blue shale with gypsum at	329 and 364—400 and other spots to 426.	
400 ft., Jan. 16.		
Gypsiferous dolomite	18	444
Light dolomite	19	463
Dark brown dolomite	47	510
Niagara (Guelph)—		
Light dolomite	60	570
White sandy dolomite	15	585
Good water at 575 feet. 589 feet, Jan. 29.		
Hard mixed cherty dolomite	7	592
White sandy dolomite	196	788
681, Feb. 10; H_2S water for over 100 ft; 870, March 23.		
Brown and mixed dolomite	232	1020
Lockport (?)—		
Limestone	90	1110
Rochester (?)—		
Blue shaly dolomite	35	1145
Brown cherty dolomite	5	1150
Light dolomite	16	1166

As neither the previous well nor this shows the Medina Lorraine and Utica shales, at least the middle group of which is known to exist, it follows that at the bottom of the well the dip from the Neebish Island well must be *over* 1200 feet in 30 miles, or over 40 feet per mile by about a foot for every 30 feet of strata of these groups. If they are 600 feet thick, as is quite likely, then the dip will be 60 feet per mile.

An estimate of 600 feet for this group, though very much more than any previous Michigan estimate, is not out of harmony with estimates in Canada, and the following well from its position should show only about the lower third of the interval between the Niagara and Trenton.

BAY DE NOC.

Escanaba, Delta county, S. W. ¼ of N. W. ¼ of Sec. 8, T. 39 N., R. 21 W.:

Pleistocene—		
Gravel and clay	9	
Lorraine (Hudson R.)—		
Blue shale	45	54
Fossiliferous shale	13	67
Brown shale	28	95
Blue shale	20	115
Brown shale	8	123
Gray shale	70	193
Light gray shale	8	201

Utica—		
Bituminous shale	50	251
Trenton—		
Limestone	83	334
Fossiliferous limestone	58	389
White limestone	8	397
Dark limestone	9	406
Quartzite	6	412
Limestone	44	456
Quartz	1	457
Limestone	24	481
Blue shale	4	485
Black limestone	14	499
Limestone	19	518
Blue shale	4	522
Sandstone, soapstone and limestone	38	560
Red clay shale	1	561
Sandy shale	1	562
Limestone, soapstone and sandstone	66	628
Crystalline limestone	12	640
Depth of hole	640	

ASPHALT IN THE UPPER PENINSULA.

Near by at Rapid River there has recently been considerable interest in an asphaltic oil, which occurs in cavities in the Trenton limestone. I take no stock in the idea that there is a great pool of it at a considerable depth in a "Synclinorium," but it might occur in fissures in the Trenton, where covered by clay drift, and especially where covered by the Utica black shales. I take the dip of the formation to be fairly uniform to the southeast and not less than 40 feet to the mile. Both where it is struck in borings and in the outcrop, the Trenton generally shows signs of oil. In particular in cavities where exposed along Rapid river there is more or less semi-fluid, dark-brown, almost black oil residuum or "gum," which gave Fr. Ruschhaupt of Milwaukee the following results: Odorless until heated, then gives off an asphalt smell. At 185° F. foams, fully liquid at 200° F., foaming at 300° to 350° F. Near 430° F. slight decomposition with evolution of a small amount of empyreumatic matter. At 556° F. boils, and after about one-half hour thickens, and boiling point rises. Boiled at 600° F. for three-quarters of an hour, the residue, cooled to 70° F., gave a hard, tenaceous asphalt. Perfect combustion left 5.08 per cent ash.

Soluble almost perfectly in gasoline, petroleum, ether, benzine, turpentine and chloroform, separating some water, and leaving only a small residue, to wit, the mineral and organic matter. Of the crude bitumen, 42.05 per cent was soluble in petroleum, ether, and 69.02 per cent in chloroform; none of it soluble in alcohol.

Summing up the result of distillation we have—

	1.	2.
Distilled at 212° to 347° (mainly water)	25.	2.21
Distilled at 570° to 600° (mainly oil)	45.36	46.55
Asphalt	24.56	46.73
Balance ash or decomposition products	5.08	4.51
	100.00	

No. 2 is the result of a second test by Ruschhaupt.

The oils were soluble in all the solvents mentioned except alcohol. Mr. Ruschhaupt says there is no petroleum in the distillate, and no paraffine, gum asphalt being the only base. A company has been formed at Mil-

waukee, M. D. Kelley secretary, to see if it cannot be found in commercial quantities.

The region of interest just now is between the Rapid and Whitefish rivers in Delta county. There is said to be but a thin coating of drift.[23]

CHEBOYGAN.

Returning once more to the north and south section, we have a very deep well at Cheboygan, the samples from which just arrived in December and have not been carefully studied, but is of so great interest that we will insert a provisional record. The driller, Mr. F. P. Rust, showed me many courtesies and took for me some temperature measurements with a Green self-recording thermometer, which are elsewhere given.

I may note that "pepper and salt" generally refers to drillings from a cherty brown dolomite. It will be noticed that there are some 500 feet of shaly beds at the bottom, and neither the Utica nor the Trenton appear to be yet struck. Very curious is the alternation in the samples of typical Medina material with that which looks like Clinton.

	Total.
Pleistocene—	
Surface, till	150
Gravel, chert	203
Sand	205
Gravel and sand	230
Gravel with many dolomite pebbles	245
Sand	250
Mainly dolomite, few other grains	255
Coarse pebbles, chert, quartzite, amphibolite, etc	270
Sand, quartz largely	290
Clayey or calcareous sand	300
Broken fragments of dolomite and pebbles	334
Aug. 5, 1899.	
Aug. 8, 1899. Pebbles of granite, dolomite, etc	352
Sand	354
Sand and cherty dolomite	356
Coarser sand, fine gravel with dolomite	360
Aug. 12, 1899.	
Monroe or Salina—	
This was a brecciated acicular dolomite, with slits and round or square cavities. It worked back so that the 8-inch casing had to be reamed down to 800 feet.	
Aug. 17, 1899. Dolomite and sand	375
Large angular fragments of dolomite	380
Cherty dolomite	438
Aug. 28, 1899.	
Oct. 12, 1899. Very cherty	512
Sept 5, 1900. " " ; Sept. 12, 1900, at 540 quicksand	570
Darker dolomite	685
Nov. 27, 1900.	
Still darker dolomite	700
Red shaly stuff	850-900
At 1050, water which "dissolved" red sandy shales above.	
March 6, 1901. Tubing to	1050
	1100
Red and blue shales	1300
March 9. Dolomites, gypsum and brine (61° 6F at 1360)	1360
(Just below 1400, March 12, 1901, brine)	1460
Dark dolomite	1475
Lighter dolomites	1478
Buff dolomites speckled with chert	1525
Niagara (Guelph)—	
	1550
Light cherty, March 26	1565
Lighter brown	1575
Finer powder	1585
	1615
No. 1, light	1625
No. 2, red rock, slow eff. in acid (1635)	1635
No. 3, red rock	1640
	1652
Coarse chips, dolomite	1665

[23] Artesian wells are struck at 250 feet, more or less.

Fine grained light dolomite	1670
Coarse chips dolomite	1700
" dolomite	1775
" dolomite	1868
" little darker, a little black shale	1880
Large pieces, dark bituminous	1904
" " " "	1942
Smaller pieces " "	1956
Lighter	1963
Much chert	1980
Coarse chert and dark dolomite	1997
June 13. Fine brown and white chert, agate, quartz	2005
"	2014
Brown	2027
Coarse dark with black shale	2033
Brown	2040
Very fine powder	2046
Lockport—	
Brown pepper and salt dolomite	2065
Light colored	2070
Coarser brown	2073
Coarse pepper and salt	2077
Fine grained	2080
Some with quite a little darker fragments	2090
" " " " " "	2094
Finer grained and no darker	2105
" " " " "	2110
" " " " " (oölitic?)	2115
Similar but with more rusty pepper and salt appearance	2123
Rochester Shale—	
With darker fragments	2136
All darker	2143
Slightly lighter	2150
Very dark	2165
Black to drab, black tinge	2170
Dark	2173
Lighter	2180
Tends to shale, dark, not so shaly (2200)	2206
Clinton—	
Rusty white limestone	2236
" " "	2245
Bluer slightly shalier	2252
Blue shale and limestone	2257
Bluish shaly limestone	2261
Similar not well washed	2265
Medina—	
*Red, shaly, with a little green	2281
White limestone	2307
*Some limestone, mainly red and green shale	2311
Limestone and blue shale	2316
Black shale and limestone	2367
Fine white limestone	2375
Red and green shale	2407
Lorraine—	
Bluish limestone	2425
Dark dolomite	2430
Very dark dolomite	2432
Very dark dolomite	2437
July 18. Very dark dolomite	2455
Dark blue shaly limestone	2750

Inasmuch as the Cheboygan well does not reach the Trenton, the dip of the same from Neebish, about 45 miles north, must be over 60 feet per mile, but I do not think it is over 66 feet per mile.

GRAYLING.

A scientifically important well has been put down by T. Percy for Salling, Hanson & Co. It is the quickest sunk of its depth of any in the State, being started the last of January and reaching 325 feet March 11, having met quite a little quicksand. By the 21st it was down about 500 feet. By April 29 it was down 2200 feet, and was finished May 6 at 2750[24] (?) feet.

[24] Detroit Free Press, May 7, 1901.

The record from the samples is as follows:

Pleistocene—		
Sand	50	55
Till	50	100
Mainly sand, some clay and gravel, plenty of water	200	300
Sandy clay, till	25	325
Coarse cement, sand, etc	40	365
Lower Grand Rapids—		
Calcareous sandstone	15	380
Dark limestone	28	408
Gypsum!	132	540
(Record probably imperfect)		
Coldwater—		
Blue calcareous shale, 8 in. casing to 600 feet	35	575
Blue shale	385	960
Limestone	190	1150
Blue shale	390	1540
Berea Horizon (?)—		
Red and blue shale	50	1590
Neodevonian shales (Antrim Shales)—		
Dark shale	210	1800
Blue shale	100	1900
Green and black shale	100	2000
Green and blue shale	125	2125
Bituminous black shale	40	2165
Mesodevonian (Traverse Group)—		
Blue argillaceous limestones	210	2375
Blue and buff dolomites	50	2425
Light limestones	75	2500
Buff dolomitic limestones, last sample.		
Temperature 95. 9° F. at 2600 ft.; at 2625 ft. bottom of well when sounded with steel tape, Aug. 6, 1901. This may have reached the top of the Dundee or Corniferous.		
Brine, Sp. Wt. 1.138, strong in earthy chlorides		2750

If this well does not reach the top of the Dundee,[25] it reaches nearly the horizon of the top of the Cheboygan well,[26] and the dip, since the well is 1140 A. T., or say 550 feet higher, would be somewhat over 31 feet per mile, which is similar to that which we found from Alpena to Killmaster. It is not surprising that it is less than farther north, for we are nearer the center of the basin.

LAKE MICHIGAN SHORE.

MUSKEGON.

There have been a number of deep wells put down here at various times for various purposes, mainly for salt manufacture. Omitting the nearly fresh water wells which go less than 700 feet down into the Marshall sandstone, we have:

I. The oldest and farthest west is the Whitney or Truesdell well, also called the Hacker well, about 586 feet A. T. Reported by Rominger.[27] It is 1230 to 1600 feet deep.

II. The Mason well, 23 feet above the lake, began in January, 1872, and in June, 1874, reached, at 2000 feet, 50 feet of salt-bearing rock. In January, 1875, it was 2400 feet deep, cased 225 feet to rock, with 1400 feet

[25] It is possible it does not penetrate the Traverse, but I think that it does and that the filling in at the bottom is due to the blue shales at the bottom thereof.
[26] Supposing there were no drift, the well would probably begin in the Corniferous.
[27] Vol. III, Part I, p. 84, of our reports.

of 4⅝-inch casing inside. This was reported in Vol. V,[28] and the only additions we can make from recent data are that from 625 to 685 feet are beds of sandstone or limestone, and that the petroleum and gas located as about 1200 feet down is probably near the horizon of the Berea Grit, as the quality of the oil indicates, but the quantity is much over-estimated. The brine at 2030 feet is from the Dundee, judging from the analyses.

MUSKEGON BRINE ANALYSES.

	1.	2.	3.	4.	5.
$CaCl_2$	58.205	54.10	77.74	40	57.69
$CaSO_4$	.548	4.22	tr	tr	.29
Al_2O_3	tr	.....	.....	.....	.....
Fe_2O_3	tr	.....	.....	.....	.....
$CaCO_3$	.....	small	.....	.....	.....
$MgCl_2$	17.034	14.97	28.6	.....	6.41
$MgBr_2$	2.346	2.37	tr	.....	.....
KCl	.....	22.16	.....	.....	.....
NaCl	174.933	158.17	129.46	280	193.78
Sum	233.103	255.99	235.8	320	258.17
Water of crystallization, etc.	33.3	.....	.....	.....	.....
By Evap.	236.4	.....	.....	.....	.....
H_2S	present.	small	.065	strong	.....

1. A. B. Prescott, Sept. 8, 1883, at 15.6° C. Sp. Gr.=1.20342, neutral, sediment of iron sulphide, Ryerson well, pump at 1650—cased to 1400 feet, depth 2050 feet and brine probably from last fift feet, K probably included with Na.
2. C. A. Crossman, Sept. 25, 1883, at 62°.5 F. Sp. Gr.=1.21, Ryerson well.
3. H. Drasch, Sept. 29, 1881, at 90° F. Sp. Gr.=92° brine, NaCl by difference residue of salts? This, 4 and 5 are from the same well, probably not a pure brine.
4. S. S. Garrigues, Aug. 12, 1881, Sp. Gr.=1.210, evidently very rough.
5. Prof. DeLa Fontaine, of Chicago, at 65° F. 1.215 Sp. Gr. Computed from pounds, ounces and grains per gallon, supposing Av. weight to be used, and the Imperial gallon of 10 lbs. The gallon may be the U. S. gallon by measure, in which case the figures should be divided by 1.005. Nos. 3, 4, and 5 are from the Mason well, when cleared out and torpedoes exploded at 2015 and 2035, left blocked below 2100, 102° to 105° Salometer brine.

III. The Ryerson-Hills well is farther east, about 588 A. T., and a record could be obtained complete only to 1427 feet, as follows:

Pleistocene—		
Sand	65	65
Clay	135	200
Hardpan	8	208
Hardpan, sandy spots, and shale	90	298
Lower Marshall and Coldwater—		
Dark and light shale (? see V.)	200	498
Lime	4	502
Shale	20	522
Lime	1	523
Light shale	20	543
Lime	2	545
Light blue shale	40	585
Lime	2	587
Light blue shale	15	602
Hard lime rock	80	682
White and blue shale and streaks of lime	195	877
Red shale	8	885
Hard lime	3	888
Dark and light shale	222	1110
Lime	5	1115
Loose shale	312	1427

[28] Plate XLIII.

This well was continued to between 2050 and 2200 feet and the pump set at 1650 feet, and at 40 strokes per minute gave 52½ gallons of brine in 3 to 4 minutes. It was cased 200 feet to rock, then 1400 feet (shutting off the oil horizon), then to the brine. Early in 1900 it was cleaned out, plugged at 1200 and tested for oil. It yields a little. I made temperature observations on it July 18. It was full of water, with a little oil on top, to the top of the casing.

IV. Near the Ryerson well, but closer to the water, a well was put down for oil in 1900. The record of the Ryerson well was used for comparison, and the new record, which was not kept in detail, is said to be about the same.

Surface	114	214
Shale and lime	161	375
Water bearing strata	25	400
Shale, etc		
6¼ inch casing to		730
A little salt and oil at		1227
Dry at		1515

V. A well was put down in the fall of 1900 about 44 feet southwest of the Mason well and about 12 feet above the lake, for the Michigan Oil Company, C. K. Macfadden, manager, of which Prof. McLouth kept a careful record for me, with a number of samples, as follows:

Pleistocene—		
Sand becoming finer downward	60	60
Calcareous blue clay free from pebbles	163	223
Gravel in clay and sand, till	12	235
Marshall—		
White micaceous sandstone	105	340
Coldwater—		
Blue micaceous shale—drilled 65 feet in 7 hours	280	620
Harder shale with carbonates of iron and lime-drilled 70 feet in 10 hours	80	700
Soft blue shale, calcareous	190	890
Brown limestone	24	914
Flagstones, shales with thin laminæ of white sandstone and calcareous bands, drilled 40 ft. in 4½ hours, and once 6 ft. in 33½ minutes	361	1275
White very fine grained micaceous sandstone or silicious shale, yielding a little oil	18	1293
Sandy shale	27	1320
Shale, somewhat darker at bottom	180	1500

Now it is about 86 miles across to Milwaukee, where the feather-edge of the Hamilton and Helderberg rocks appear, which are not less than 1700 feet down at Muskegon. The dip to the center of the basin should therefore be, normally, 20 feet per mile or more.

Unfortunately the wells so far are so close together and have such inaccurate records that there is no sure indication as to whether the local dip conforms to this or not. The first thing to do, therefore, if explorations are to be continued, is to spread the wells so as to see what prospect there is of abnormal dips, and incidentally it may be that some place will be found where the sandstone at about 1200 feet, which is so very fine-grained, will be more porous.

If the "red shale" and limestone at 877 to 888 feet in the Ryerson is the same as the brown limestone at 890 to 914 feet of the last well, the bed in the Ryerson well would not be deeper, as it should according to the normal dip. This may be a slight indication of an abnormally flat dip.

MANISTEE.

Near Manistee the wells are more scattered than at Muskegon. (See map, Plate X.) They extend five or six miles from the Canfield and Wheeler well, close to Lake Michigan and about 592 A. T., to the wells at Stronach and Filer City at the head of the lake. Four plates are given in Vol. V. Mr. J. J. Hubbell has kindly assisted me with notes on these wells, locations, elevations and profiles. There are some twenty-eight[29]

No.	Owner.	Location.	Elevation above lake.	Total depth.	Depth to top of salt rock.
1	Canfield & Wheeler	0.7 mile N., 0.68 mile W., Sec. 11, T. 21 N., R. 17 W.	12	2,270	1,900
2	" "	0.7 mile N., 0.68 mile W., Sec. 11, T. 21 N., R. 17 W.	"	1,947 1,926	
3	Manistee Lumber Co.	.28 .72 Sec. 1,			
4	" " "	" " "			
5	Louis Sands	.04 .44			
6	" "	" " "			
7	Canfield S. and L. Co.	.1 .08 "			
8	" " "	" " "			
9	R. G. Peters	.92 .28 Sec. 7, T. 21 N., R. 16 W.		2,026.5	
10	" "	" " "			
11	" "	" " "			
12	" "	" " "			
13	" "	" " " " "			
14	Buckley & Douglass	.54 .40 Sec. 12, T. 21 N. R. 17 W.			
15	" " "	" "			
16	" " "	" "			
17	" " "	" "			
18	" " "	" " "	30	2,015	1,955
19	Canfield S. and L. Co.	.18 .36 Sec. 7, T. 21 N., R. 16 W.		1,947	
20	" " "				
21	State Lumber Co.	.18 .21 Sec. 12, T. 21 N., R. 17 W.			
22	" " "				
23	" " "				
24	Louis Sands	.69 .97 Sec. 18, T. 21 N., R. 16 W.			
25	" "				
26	Filer & Sons	.96 .86 Sec. 19 T.			
27	Union Salt & Lumber Co.	.72 .68 Sec. 20	25	1,962 or 2,016 to 2,025	1,924 or
28	" " " " "	" " "			

J. P. Miller and Co. report that they put down four wells 1900 feet deep, two each for the Engelman Saltworks and Chas. Rietz and Bros., in March, 1883, and Feb., 1882, respectively. The depth given is however obviously only a round number.

[29] Jan. 1, 1901.

in all, but of many we have few notes, only the depth to the salt, or the total depth. Beginning at the west, we have the Canfield and Wheeler wells already described.[30] It is important to add, however, that the well was later deepened some 500 feet for them by T. Percy. The samples were sent me and show that they entered the white Guelph dolomites, which form the opposite shore of Lake Michigan. Analyses[31] agree therewith. It appears, accordingly, that the dip across the lake is not less than 39 feet per mile, and probably not over 50, a dip intermediate between that from Milwaukee to Muskegon, and that from Neebish to Cheboygan. Their second well was drilled 1926½ feet deep, but probably not to the bottom of the salt.

The Buckley & Douglass Lumber Company well No. 5 is not hitherto reported, and to the kindness of Mr. Hubbell we owe a record. It is higher than the Canfield and Wheeler wells, being about 610 A. T. The record is:

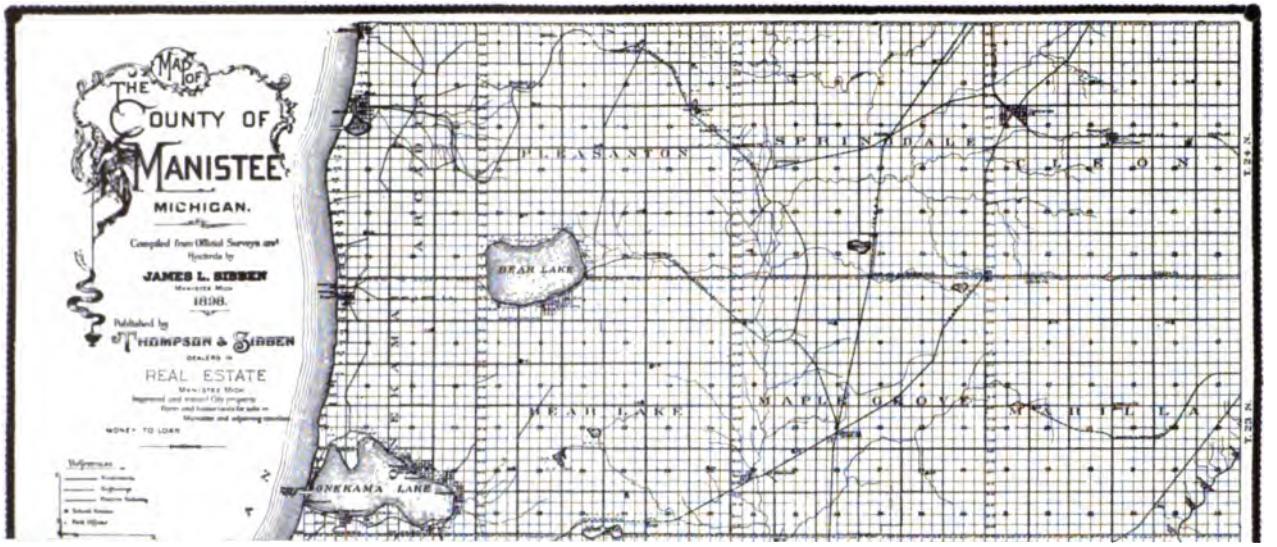
Pleistocene—		
First casing 10-inch pipe driven 400 feet		400
Second casing 8-inch pipe to bed rock through sand, clay and gravel	616	616
Devonian—		
Hard shale	324	940
4½-inch casing to		985
3-inch casing to		1032
A 3-inch pipe for brine inserted 985 ft.		
Limestone	630	1570
Soft shale, 7-inch hole drilled, brass lining to caving rock	110	1680
Silurian—		
Limestone, 6-inch hole, no lining	195	1875
6-inch hole brass lining caving rock salt and gypsum	20	1895
Limestone, 5-inch hole, no lining	90	1985
Brine cavity	30	2015

An air lift is used, the air being carried down to 985 feet and the brine raised from 400 feet to the surface.

Upon the names of the rocks we evidently cannot depend, but the salt is plainly about 70 feet deeper than in Canfield's well, and it may be that the casing from 1460 to 1520 feet in the latter hole corresponds with that from 1570 to 1680 feet in this, but the Canfield record is as unsatisfactory as this, in that the samples do not at all match the "log." Between this Buckley & Douglass well and the Peters well[32] the correlation is easier. The bottom of the salt being in one case at 2015 feet in the other at 2026, the two are about on a level there, but the Peters well showed quite a little oil and gas at 1905 feet. The soft shale at 1490 to 1600 feet in the latter must be that at 1570 to 1680 feet, in the former, however, being at the base of the Traverse Group, and 960 feet will correspond to 940 feet.

Now when we go down to the head of the lake at Stronach,[33] we find the salt down at only 1930 to 1964 feet. The Bell (Marcellus) shale at the base of the Traverse is higher, too,—from 1450 to 1625 feet,—with signs

[30] Vol. V, Plate XXXI. Letter of E. D. Wheeler, Feb. 13, 1900. J. J. Hubbell, Jan. 16 and 19.
[31] No. 322 in Water Supply Paper No. 31 of the U. S. G. S. is of the brine before deepening, No. 323 after. Compare the Britton analysis.
The elevation of the two C. and W. wells is but 12 feet above the lake.
[32] Plate XXXII.
[33] Plate LXV. Mr. Hubbell says that the Union Salt and Lumber Co. wells, 25 feet above the lake strike the top of the salt at 1949 feet and the bottom as supposed at 1982 feet, but as the wells afterwards spontaneously deepened to 2016 respectively to 2025 feet, he doubts this latter fact.


MAP OF
THE COUNTY OF
MANISTEE
MICHIGAN.
Compiled from Official Surveys and Records by
JAMES L. SIBBEN
1898.
Published by
THOMPSON & SIBBEN
DEALERS IN
REAL ESTATE
MONEY TO LOAN
PLEASANTON
SPRINGDALE
BEAR LAKE
BEAR LAKE
MAPLE GROVE
ONEKAMA LAKE
T.24 N.
T.23 N.

in a
tota
well
was
sent
form
It a
feet
from
Thei
botto
Th
repo
than

Pleist
Fi
Sec

Devon
Ha
4-i
3-i
A
Li
Soc

Silurio
Li
6-i
Li
Bri

An
raise
Up
is pla
the ca
from
as thi
Buck
The b
the t
little
latter
the ba
No
the sa
the ba

[88] Vol
[89] No.
No. 82
The
[90] Pla
[91] Pla
the lak
as the w
latter f

of oil and gas immediately beneath. The base of the black shales is, however, if rightly given, at about the same depth, 970 feet.

Therefore, instead of corresponding beds being 200 or 300 feet deeper than in the Canfield and Wheeler wells at Stronach, as they should be, were the dip across Lake Michigan continued, they are about as high, and higher than in the beds between. Gas was also noted at 600 feet.

It seems to me, therefore, that near Stronach there must be an arch, which ought to collect oil or gas in commercial quantities at its crest. But, of course, as there are no wells southeast of Stronach for many miles, we cannot tell either its course or position as yet.

SALT.

SALT.

The development of the salt business has been mainly along the St. Clair and Detroit rivers. A number of the well records have already been given, e. g., those at St. Clair, Marine City, New Baltimore and Detroit.

At St. Clair the salt comes at 1668 feet in well No. 3, with the following record:

Salt	25	1693
Limestone	77	1770
Mixture	15	1785
Salt	20	1805
Mixture	5	1810
Salt	45	1855

At Marine City the Michigan Salt Company have—

Salt	25	1595
Limestone	10	1605
Salt	10	1615
Limestone	11	1622
Salt	125	1751

The Davidson and Wonsey well had black shale at 600 feet, and at 1565 feet 250 feet of salt.

The well of the Pennsylvania Salt Company, below Wyandotte, is said to go through a bed of salt 103 feet thick at about 1200 feet.

The Pennsylvania Salt Company have a well near the Lake Shore tracks and Ecorse river with 25 feet of salt at 830 feet, and other beds below,—80 feet between that and 1050 feet.

Salliote and Ferguson, at the River Rouge, also have salt wells, and the Michigan Rock Salt Company are putting down a shaft to mine rock salt. The waters above the rock are strong of H_2S and their amount and character is the chief difficulty in the way of mining it, which has been under consideration now for some years.

The rock salt beds themselves are dry and water from the St. Clair or Detroit rivers is pumped down to dissolve the salt. In one case Mr. Hill, for many years salt inspector, found that an off tinge in the salt which was causing much trouble, was due to the water not being quite pure at the intake. When this was changed the difficulty was remedied.

The temperature of the upcoming brines is, according to reports, remarkably low, and deserves farther study.

The rock-salt brines contain more lime, especially as sulphate, and the salt is more likely to cake and be "sharper," and so for some purposes less desirable, than the natural brines. A group of analyses of these brines at Detroit is as follows:

Analyses of Detroit brine, from M. M. Green:[1]

	Jan.	Feb.	Mar.	April.	May.	June.
$NaCl$	311.72	312.69	309.45	308.78	311.78	310.16
$MgCl_2$	.228	.258	.278	.278	.219	.255
$CaSO_4$	5.943	6.04	5.892	6.05	6.05	5.754
$CaCl_2$	.248	.....	.265	.210	.196	.307

As the analyses show, they are very free from the earthy chlorides as compared with the natural brines, and hence there is not much of bittern to throw away.

With these natural brines the quality of the salt is affected, and a disproportionate amount of the heat[2] is needed if the evaporation of the brine is carried too far.[3] Hahn's papers contain a great many analyses. The following[4] is an analysis of a Saginaw valley brine by E. M. Vanflint:

$CaCl_2$	25.91
$CaSO_4$	1.19
$FeCO_3$	.92
Al_2O_3	.22
$MgCl_2$	6.27
$MgBr_2$	2.36
I, K, Li	tr.
$NaCl$	179.49
H_2O	783.73
	1000.00

In the Saginaw valley the most interesting feature is the putting down of a number of wells at St. Charles, to use the waste of the coal mines. These wells pass through the lowest coal at about 425 feet, and below this are said to find a good deal of limestone, striking the "salt rock," the Napoleon limestone, at 700 to 810 feet.

It is a pity that the deep well at Bay City, whose record is elsewhere given, was not put down through the salt formation so as to touch the Niagara beneath, and see what there may be in the way of rock salt beneath the valley, and it may be hoped that sometime there may be, even for the scientific interest of the matter apart from any definite prospective value, a hole in the lower peninsula as deep as in the upper.

[1] In grammes per litre.
[2] See a series of articles by H. C. Hahn in the Berg Huettenmænnische Zeitung for 1867 and 1881.
[3] Hahn, loc. cit., recommends concentrating Saginaw valley brine only to a density of 1.25.
[4] And many more will be found in U. S. G. S. Water Supply Paper No. 31.

METEORITES.

There has recently come to my office a paper by Merrill and Stokes[1] on a meteorite which fell July 10, 1899, on Thomas hill, on the Saugatuck road near Allegan. "The total weight cannot have been far from 70 pounds."

Specks of magnetic matter are common in all the samples of drillings, and a test with copper sulphate shows that metallic iron is often present. Usually these can be safely assumed to be worn from the drill, but there are a few cases, where the softness of the associated rock or the abundance of the iron or some other feature makes this explanation hardly satisfactory. An iron mica decomposed in the presence of organic matter seems to be responsible for one case. Are some of them meteoric?

The numerous suites of specimens representing the geological column of the State, and the Allegan meteorite together suggest an interesting field of research. According to the Encyclopedia Britannica, probably about 20,000,000 visible meteorites or shooting stars strike the earth each day, and if all those which the telescope would reveal are counted there would be perhaps 20 times as many. Suppose each to contain one gram of matter of which 10 per cent was nickel. The surface of the earth is about 510,000,000 square kilometers. Thus the average contribution each year to each square kilometer of the earth's surface would be about 28.6 grams, so that if one millimeter in thickness of a certain stratum was formed each year and received an average share of meteoric dust, a square kilometer in area, 1,000 cubic meters in bulk, would contain 28.6 grams.

If the stratum had, for instance, the specific gravity of 2.86, which is nearly that of many limestones, the bulk in question would weigh 2860 metric tons, and the percentage of nickel contained would be one-millionth of one per cent.[2] If, therefore, methods of chemical analysis were refined enough to enable us to determine such small amounts of nickel or any other element characteristic of the meteorites, we could get a notion of the rapidity with which any bed was formed, or if we should test a sample representing the average of the Devonian strata, which our well samples would readily give us, we could find their mean rate of deposition, and from that infer the duration of the Devonian period. In fact, we have material enough pretty well to infer by the same way the duration from the end of the Potsdam to the beginning of the proper coal measures. Even now we can see that any estimate which would allow thousands of millions of years for the accumulation of the 6,000 feet or so of strata which represent the interval in question, is likely to be extravagant, for it would mean an average meteoric constituent of .01 per cent or more.

Chemical methods for the determination of nickel are, however, not yet delicate enough to apply this test.

---

[1] Proc. Washington Acad. of Sciences, Vol. II, pp. 41-68: Am. J. S., Dec. 1899.

[2] If the ratio of the number of meteorites falling annually be n, average percentage of any element p, thickness of stratum formed per annum t, and specific weight of the same s, to the numbers we have supposed, then the per cent of nickel in the stratum would be $nwp \div st$ 1,000,000.

GEOTHERMAL GRADIENT.

During the year my assistance has been sought by Prof. Wm. Everett,[1] secretary of the committee of the British Association for the Advancement of Science, for the study of underground temperatures.

The rate of increase in the temperature of the rocks as we go down, which is known as the geothermal gradient, is a matter of keen scientific interest, since we can gain from it some idea how long the earth has been cooling.[2] It is of especial interest in this State, because it has been reported to be uniquely low in our deepest mines, which are now not far from a mile beneath the surface. The increase is so great, nevertheless, that it is a practical question just how soon it will be a serious hindrance to mining.[3] I am inclined to believe, moreover, that when we have more facts to base our conclusions on, we shall be able to trace irregularities and find the thermometer quite useful in detecting leaky casings, locating the depth of the sources of flows, waters, etc. In fact, I have already[4] received help from the thermometer along these lines. Finally, we may possibly get light upon the movements of underground waters which, according to Prof. Van Hise, are the great conveyors and concentrators of mineral deposits.

In 1886 Prof. H. A. Wheeler published in the American Journal of Science[5] an article in which he called attention to the low rate of increase of temperature in the copper mines of Keweenaw Point, and attributed the same to the cooling effect of Lake Superior on the flanks. His observations are summarized in the following table:

Mine name.	Gradient.	Depth.	Distance between stations.	Highest temperature.	Character of lode.
Atlantic	99.5	907	796	51.6	Melaphyre.
Central	101	1950	1860	61	Fissure vein.
Conglomerate	95	617	527	48.3	Quartz p'y, Conglom.
Osceola	76.5	996	860	54.5	Melaphyre.
Tamarack	110.7	2240	2104	62.	Quartz p'y, Conglom.
Quincy	122	1931	1820	58.5	Melaphyre.

From his table we find the lowest temperatures he noted in the various mines must be[6] close to 43° (43.3° F. at 112 feet or less). Prof. Wheeler

[1] See reports of this committee in the Annual Proceedings, especially for 1882 and 1901. Also the Geological Magazine for December, 1901.

[2] Under certain suppositions, Sir W. Thomson (Lord Kelvin) estimates from 100,000,000 to 400,000,000 years.

[3] See my paper in Mineral Industry, 1895, Vol. IV, p. 767.

[4] And Mr. R. E. Bacon of the air lift also uses it right along.

[5] Vol. 32, Art. 13, pp. 125 to 137, Temperature Observations on Lake Superior Mines; also Trans. St. Louis Acad. Sci.

[6] 43.6° at 111; 42.6° at 90, 42.8° at 90, 42.3° dt 136, 43° at 136, and 43° at 111 feet respectively.

thinks that the Tamarack observations especially may be affected by the ventilation of the mine.

By meteorological observations the mean air temperature of Keweenaw Point is not far from 40 degrees.[7] Thus a mean surface-soil temperature is indicated some 4 degrees above the air temperature. The British Association report that the soil temperature for the year is usually above that of the air from ½ to 2 degrees,[8] and that this is mainly due to the blanketing effect of the snow. We refer to this point again below. Wheeler's results, therefore, agree well enough with what might be expected, for Keweenaw Point has a very heavy burden of winter snow and often the ground does not freeze all winter. Furthermore, I took the occasion of a visit to the newly opened Champion copper mine, July 24, 1901, to make some tests of temperatures, through the courtesy, and with the help, of my predecessor, Dr. L. L. Hubbard, the manager, to obtain some light on the upper temperatures. The mine is recently opened. In the north end of the third level of B shaft, 378 feet below the surface, where there was no working or drift, the temperature at the top was about 49° F., of the air 47° F., in the moist rubbish at the bottom of the level 46° F. In the second level north, 250 feet down, the thermometer left in a short hole 20 minutes or more stood at 45° F.

In the first level 130 feet down in similar circumstances it stood at about 44½ degrees.

The observation at the bottom of the mine agrees in its rate of increase with Wheeler's. The others are perhaps warmed by air convection in the mine, but agree in pointing to a mean soil temperature of 43 to 44 degrees.

Some years ago (in 1893-4) the Centennial mine drove a cross-cut from the foot of a shaft which they had sunk between 3100 and 3200 feet on the Calumet conglomerate, over to what was supposed to be the Osceola amygdaloid. The temperature at the foot of the shaft was 62 and at the end of the long cross-cut about 19 feet below the surface, 69. It was said to have been 72 degrees the previous summer. There was a fair ventilation furnished by the air drill, but the temperatures are not out of harmony with those of Wheeler for a similar depth.

In 1895 A. Agassiz, president of the Calumet & Hecla Mining Company, published in the American Journal of Science[9] some figures for that mine, to wit, 59° F. at 105 feet and 79° F. at 4580 feet, the air temperature at the bottom of the shaft being 72° F.

It is clear, however, that the upper temperature is abnormally high, probably from the effect of the mine circulation during a long term of years, while the lower temperature is perhaps a little low from the same cause. The balance of Agassiz's observations have never been published, though if they could be carefully studied with due regard to the various factors they would be of much interest.

That this gradient is not something very local and peculiar to Keweenaw Point may be inferred from a few observations in the iron country. On July 19 last, with Mr. André Formis, one of the engineers, I went to the bottom of the Lake Superior hard ore mine at Ishpeming. The bottom of this mine at the 19th level is 900 feet vertically from the surface. It is

[7] 38.6° F. at Calumet.

[8] 1882, p. 72. At the Kew Botanic Garden, 0.4 degrees F. Over the St. Gothard tunnel from 2 to 3° C. to 5 to 6°, i. e., from 4 to 10° F., here being more snow.

[9] 1895, Vol. L, p. 503.

barely opened up down there and the skip goes only to the 14th level. It is connected with but one shaft. The water in the floor of the drift was at 49° F., and a little spring in a crevice on the east side of the shaft at 48.5°. The air was at 50°,[10] and a thermometer left in a diamond drill hole five feet in for 20 minutes registered the same depth.

In the Vulcan mine at Menominee I found[11] 56° at 1210 feet; the mean annual air temperature ought to be about 40° F., but Per Larrson found that a heavy flow at 80 to 90 feet had a temperature of 44 degrees. In the same paper I quoted the temperature of the North Tamarack at 4400 feet as 84 degrees F. according to R. M. Edwards. Captain J. Hall, the mining inspector, in his annual report for 1901 says that the rock temperature at the bottom of the Tamarack No. 5, and at the Red Jacket shaft of the Calumet & Hecla, at 4900 and 4935 feet, is 87 degrees. I believe that Mr. W. E. Parnell has stated that at a depth of 4662 feet a thermometer placed against the rock and covered with cotton batting registered 82 degrees.

Considering that the tendency must be to get the lower observations not high enough and the observations in the upper levels at low temperatures if anything too high, we may say that a line, which gives values for the upper levels as low as any, and for deeper levels as high as any, must be near the truth. It implies a gradient of 1 degree F. in 107 feet. It is a pity that a careful and expert physicist like Prof. Hallock of Columbia University, who has done special work in this line, should not have been allowed to make accurate tests.

I find it difficult to get thermometers thoroughly reliable, even to a large fraction of a degree, for this work.

It will be noticed that such a gradient line points to an average soil temperature at the surface of about 42½° F., i. e., about 4° F. above that of the air temperature of Calumet. This is probably not wholly because mine ventilation has made the deep observations too low and the shallow ones too high, though that is the kind of effect it would produce, but observations of temperature close to the surface of the soil show that it differs materially, even in the average, from the air temperature, and gives us not merely a starting point from which to measure the rate of increase downward, but a measurement of the mean blanketing effect of snow, and of the physical condition of the soil, its diffusivity for heat, mean wetness, etc., for the former is very dependent on the latter.

Generally speaking, the denser matter is, the better does it diffuse heat. Air is a poorer conductor than water, and water diffuses heat (except by convection) less rapidly than rock. Accordingly a porous, dry soil is a warm soil, i. e., loses heat more slowly than a damp, heavy soil.[12]

---

[10] In a downcast shaft at the 14th level it was 43°.

[11] Am. Journal of Science, Vol. IX, June, 1900, p. 435.

[12] Hugh L. Callendar and C. H. McLeod of the McDonald chair of physics in the University of Montreal have recently published in the Transactions of the Royal Society of Canada, Section III, Second Series, 1895-6, Vol. I, pp. 1-19, and 1896-7, pp. 109-116, experiments that show not only this blanketing effect of snow, but also that the effect of sunshine can be most effectively studied.

For instance, the mean annual temperature of the soil within two feet of the surface of the ground was 47 degrees when the mean annual temperature of the air at Montreal was 42.63 degrees F.,—over four degrees higher. (Quite comparable to Keweenaw Point observations.) "It is not improbable that this difference may afford a convenient measure of the protective influence of the snow and will be found to differ materially in different years."

The maximum heat at the surface occurs in Montreal in June and July. It is coldest in December, but remains cold and the underground temperatures near 32 degrees until April.

At the depth of 9 feet the cumulative effect of the long winter cold did not come until the first of May, and that of the summer heat until the middle of October.

In Angstrooms' experiments from 1838 to 1844 at Upsala, the lowest temperature at two feet depth was March 2 to 11 (.075), and the highest July 11 to 20 (16.20° C.) and Aug. 11 to 20 (16.21° C.), while at 10 feet depth the lowest was the last of April (3.89° C.), and the maximum the last week of September (10.22° C.).

The mean air temperature for 8 years was 4.826 degrees C., and that of the soil 6.814 degrees C. At Stockholm we have for 1833-4, 6.637 degrees C. and 6.992 degrees C.; for 1842-49, 7.994 degrees C. and 8.61 degrees C. respectively, showing how much they vary according to the local climate.

Observations of underground temperatures at Grayling and at the Agricultural College have been published, but not for the winter months, and therefore give us no data as to the blanketing effect of the snow, though they may be made to let us know the thermal capacity of the soils.[13] It would be interesting to compare the upper and lower peninsulas in this respect, for the latter has much less snow.

The same variation in diffusivity also exists among rocks, and the following tables, compiled mainly from the report of the British committee aforesaid, are arranged to bring that out, and also the obvious fact that generally the lighter and more porous the rock the poorer conductor it is.

	Diffusivities.	
Quartz	.0086	
Sandstone	.006	Conducts 8 per cent better wet.
Flagstones	.0046	
Sand dry	.0009	Kew experimental garden.
Wet	.007	" "
May 23—June 6	.006	Callendar and McLeod, (from .0379 to .0015).
Ave	.0036	Callendar and McLeod.
	.00872	Forbes and Thompson.
Sandy loam	.0054	1889 Report Brit. Asso.
Slate	.004	
Clay slate	.0027	
Clay	.0025	
Shale	.0019	
Knoxville pink marble	.00757	B. O. Peirce.
Vermont white	.00681	Fine grained.
Carrara	.0050	
Limestone	.0052	
Granite	.0053	
Flint glass	.00260	B. O. Peirce.
	.00277	" "
Crown glass	.00245	Oddone.
	.00243	Leese.
Pumice	.0006	
Schemnitz hornblende andesite	.0029	
Trachyte	.001	Ayrton & Perry Brit. Ency.
Trap	.0078	
	.007	Brit. Ency.,
Serpentine	.0044	
Rock salt[14]	.0113	
Copper	1.077	Brit. Ency.
Water	.0022	" "
Air[15]	.0016	" "
Wood	.0013	" "

From these tables we may infer that other things being equal, rocks containing much copper will have a high diffusivity and a small gradient, and that there will in general be no marked difference between sandstone, limestone, and our Lake Superior traps and granites. But surface

[13] Reports State Board of Agriculture, 1888, p. 187; 1889, pp. 85 to 101; 1890, pp. 143 to 152; 1891, pp. 92 to 97.

[14] This seems rather high. Has not the diathermic effect of radiant heat been combined?

[15] Air is a poorer conductor than water, when not allowed to circulate. See pumice and wood.

materials, whether sand, gravel or clay, and shales will have a much less diffusivity and the temperature will rise more rapidly. Circulation of water in a hole will tend to make the gradient appear too low, and the circulation of water downward at the sides of a synclinal basin would make a low gradient, while at the center where there was upward pressure the reverse would be the case.

It will be very interesting to compare the results we have found in mines with those in deep wells. There is one such at Lake Linden all the way in red sandstone, which flowed, and another was recently put down at Grand Marais, which did not flow. Observations should be made in these wells.

There are also some deep artesian wells. which flow along the shore of Lake Michigan, the data concerning which are not very satisfactory. Back of the S. M. Stephenson house at Menominee is a well over 500 feet and less than 1000 feet deep, probably about 800 feet, which is flowing with 15 feet head and a temperature of 55½ degrees F. Probably much of the way it is through Trenton and calciferous dolomite. The mean soil temperature ought to be 2 degrees warmer than on Keweenaw Point,—say 45 degrees, and the mean gradient 1 degree in 80 feet.

At St. Ignace a deep well was put down by A. W. Palmer 1155 feet. The record already given may be summarized as follows:

Dolomites and gypsum.....	174	174
Red and blue shales and gypsum.....	226	400
Dolomites (often very light colored, of the Niagara formation, with abundant water from 575 to 681 feet, and more at 1040 feet)	755	1155

The temperature of the flow was 51° F. This is about 2 degrees less than at Cheboygan and Alpena at that depth.

Not far off, at Cheboygan, we have much fuller information. I attempted to get more data at St. Ignace, but the thermometer broke. At Cheboygan the water works are supplied by a well 408[16] feet deep. It would flow naturally, but the yield is increased by an air lift, and the temperature is 51.8°.[17]

Another old well near the McArthur's mill and the river, which is said to be 839[18] feet deep and cased to 70 feet but is loosely filled up, gave a flow temperature of 48.7° F. on March 10, 1901.

There is another well about as deep (400 to 500 feet) as the water works well on the east side of the river near Nelson's mill. But the interesting well is the one put down recently over 2700 feet. I visited this March 11, 1901. The well was then down 1380 feet and the temperature[19] was 61.6 degrees F.

The mean annual temperature of Cheboygan according to the weather service is 41.6 degrees. At the conclusion I was not able to be present, but a series of tests were made by Mr. F. P. Rust, the contractor, and I

[16] Other reports say over 400 and 464 feet.
[17] Green thermometer 7536.
[18] It is also said that it is 900 feet deep and over 200 feet to bed rock.
[19] By Green thermometer 7812 attached to the top of the baller, in a perforated brass case.

believe him to be intelligent and careful. The results[20] are: at 100 feet, 53°; 400 feet, 51°; 700 feet, 51.5°; 1000 feet, 55°; 1300 feet, 60°; 1400 feet, 60.4°; 1700 feet, 63°; 1800 feet, 64°; 2000 feet, 65°; 2300 feet, 68°; 2700 feet, 73°. They indicate plainly difficulty in reading fractions of a degree, but taken together with the temperature of the water at the water works from 400 feet and my own reading at 1360 feet, agree quite fairly in a low gradient from 400 feet down of more than 100[21] feet to a degree, and also a much higher gradient from the surface to bed rock, even supposing the mean soil temperature to be 4 degrees more than that of the air. Fissures and water were fairly often encountered. The rock was very largely dolomite. This gradient matches fairly that on Keweenaw Point.

Going down to the opposite end of the State at Britton to get a well through similar rocks, thermometers let down on the rope of a bailer to 945 and 1617 feet read 59° and 53° F. respectively. There is a brine at the bottom of the well, not so strong probably as a little that is seeping higher up. But taking the average of these two observations (63.3) as the temperature at the mean depth (1281 feet) we get a gradient, if the soil temperature is a little above that of the air temperature (48 degrees), about the same as at Cheboygan.

The well of the Diamond Crystal Salt Company at St. Clair was tested at 1635 feet and gave 71.2 degrees. Here, however, we have a new disturbing factor. Water has been pumped down for a good many years in this and adjacent wells to dissolve rock salt, though this well has been idle for some months. Only 200 feet away the tools were in a well which was being fixed. Near by the Salutaris well is said to have flowed at 92 feet with a temperature of 51 degrees, and now, being pumped, stands at 52 degrees, while the Oakland mineral well, 1200 feet deep or so, being pumped, is at a temperature of 69 degrees F.

The old Wells boring at Port Huron, recorded in Vol. V but now stopped at 838 feet, was there at 57.5° F.; at 600 feet, 55.3° F.; at 300 feet, 54.2° F. (?)

The mean air temperature of the neighborhood is about 46 degrees, and it is clear that for the first two or three hundred feet or so there is a very rapid rise of temperature, or the soil temperature is a good deal higher. Even thereafter the gradient must be greater, perhaps about 1 degree F. in 65 feet. There is more shale and gypsum in these wells than in the previous ones, and the record is perhaps comparable with the lower part of that at Bay City.

This I have already mentioned and the record is elsewhere given.[22] The East Saginaw first well flowed with a temperature of 47° F. at 102 feet, 50° at 293 feet, 51° at 531 feet, and 54° at 617 feet. The air temperature is 45.4°.[23] Hahn also gives the mean temperature of the brines as 60.4° F.

[20] By Green thermometer 9114. Mr. Rust followed detailed instructions from me, and noticing the irregular character of the first three observations repeated them to see if any error could be detected, but could not find any. He also writes: "Please note the temperature at 100 feet is 2 degrees warmer than at 400 feet and ½ degree warmer than at 700 feet. This seemed a little strange to me, so when we had gotten all through I went over the first three tests again, but was unable to find the error." Previous to his test of the temperatures, however, he had plugged the well at 1600 feet and had been testing a brine at 1400 feet, and no doubt convection currents have upset these somewhat. There were casings down 950 feet and 1050 feet at the time.

[21] From 1400 to 2700 feet, 1 degree in 103 feet; from 400 to 1360 feet, 1 degree to 102 feet; from 400 to 2700 feet, 1 degree in 104 or 108 feet, while between the temperature at 400 feet and that of the air there is a drop of 10 degrees.

[22] Am. J. S., Vol. IX, p. 434.

[23] Hahn, p. 305, Berg. Hutt. Zeitung, 1867.

from a depth of from 600 to 880 feet, probably mainly below 760 feet. Then we have Davis's observations in the Bay City well, to wit:

At 3455 feet, 97° F., thermometer No. 5688 exposed 8 hours.

At 2934 feet, 90.1 and 90.2° F., thermometer Nos. 5688 and 5690 respectively exposed 1 hour.

At 1793 feet, 77° F., thermometer Nos. 5688 and 5690 exposed 30 minutes.

At 1793 feet, 71° F., thermometer No. 4708 exposed 50 minutes.

At 1304 feet, 65° F., thermometer No. 4708 exposed 1 hour.

It is pretty plain that in the Saginaw valley the snow blanketing is not marked. The mean gradient of 1 degree in 67.07 feet agrees so nearly with intermediate observations that the departures from it may be assigned to insufficient exposure and difference in thermometers, though I am tempted to assign the decrease in gradient at the end down to 1 degree in 75 feet to the fact that we are getting into the same beds that gave the low gradients at Cheboygan and Britton. Still it may perhaps be laid to aqueous circulation.

I have in times past doubted the high temperature given for the bottom of the Alma well, 98 degrees at 2803 feet, but I have more faith in it for various reasons now:

The blanketing effect is well marked at Alma. With a mean annual air temperature of 45 degrees, shallow flowing wells from 30 to 80 feet deep vary little from 50 degrees temperature.

Again, in spite of various difficulties, I managed to get a thermometer down to 900 feet and found the temperature 69.6 degrees. The well had not been pumped for some time, but has been pumped the past 13 years perhaps 50,000 gallons a year.

Finally, some observations on the new Grayling well, which is similarly located and goes through similar strata, show a similar gradient, and allowing for an initial 3° difference, have a very similar temperature at the end. The Grayling observations are:

On June 4, 93.8 degrees F. at 2376 feet

On August 6, with No. 7815:

95.9° F. at 2600 feet, thermometer exposed 1 hour and 18 minutes.
89° F. at 2150 feet, thermometer exposed 1 hour and 20 minutes.
58.4° F. at 900 feet, thermometer exposed 2 hours and 30 minutes.
51.8° F. at 500 feet, thermometer exposed 1 hour and 5 minutes.

There was very little mercury forced through the neck of this thermometer at this last reading and the reading may be low. The water was about 26 feet from the top. The gradients are:

2600 to 2376 feet, 1 degree in 111.3 feet.
2600 to 2150 feet, 1 degree in 65 feet.
2376 to 900 feet, 1 degree in 59 feet.
2150 to 900 feet, 1 degree in 40.8 feet.

This very low gradient is probably all the way in fairly dry shale.

900 to 500 feet, 1 degree in 60.5 feet.

This is not reliable, as the 500 foot reading should, I think, be rejected.

900 to 0 feet, 1 degree in 60 feet.

(Supposing the mean soil temperature to be 1.2° above that of the air.) There is here not so much sign of blanketing. It is obvious here that

except again in the very last part the gradient is even steeper than at Bay City or Alma.

We have tested one other well that goes down mainly in surface deposits and shales, that at Muskegon. The mean air temperature is 46.8° F. The flowing wells from 240 feet depth on are at 53° to 53.5° F. Ryerson's well, plugged at 1200 feet but full of water, gave at 240 feet, 53.2 degrees F.; at 650 feet, 58.7 degrees F.; at 1150 feet, 67.2 degrees F.

The gradients through surface from a soil temperature assumed at 47.2 degrees, sandstone, and shale, are respectively 1 degree in 40 feet, 1 degree in 74 feet, and 1 degree in 59 feet. There is some oil in the bottom.

It certainly looks as though the facts could be accounted for by supposing a difference of air and soil temperature of ½ to 4 degrees according to location, a gradient in the surface deposits of 1 degree in 40 feet more or less, in shale of 1 degree in about 60 feet, in sandstone 1 degree in 60 to 70 feet, and in limestone, trap, and the denser rocks of about 1 degree in 100 feet. This is not far from the ratios their diffusivities would lead us to expect. But we need more facts, and especially more accurate observations of gradients, of the effect of the mine ventilation, and records of soil temperatures continuous throughout the year. The effects of oil formation and salt solution may then be eliminated.

MAMMOTH AND MASTODON.

Remains of large animals of the elephant tribe have been known ever since the early days, and are referred to in the annual report for 1841,[1] and in Winchell's report in 1850.[2]

At the Agricultural College are six teeth and half the lower jaw of a mastodon, from Eau Claire, Berrien county, which may be the one referred to by Hubbard.

It was found in digging a ditch and is well preserved.

There are also remains from Lenawee county, and a lower tooth and part of a pelvis which were sent in in the spring of 1900 from the Shiawassee river, in Howell township, by Ulysses Hilleker. They were obtained in dredging out the river for a light steamer.

During the past year two instances have come under my personal observation of especial interest, because the animal proved to be the mammoth, the rarer, it is supposed, of the two animals, mammoth and mastodon.[3]

Mr. E. R. Grinold of Grand Ledge noticed in ditching north of that town that they had cut through a tusk, and through Mr. C. V. Fuller my attention was called. I went down there and found the remains barely a foot from the surface in a little low swale which Mr. Frank Tabor, the owner, said was a duck pond 40 years ago,—in other words, a good place for a large, heavy animal to get mired. We exposed three teeth which were plainly those of a mammoth, and were lying just exposed. The teeth were, two of them 8 inches long, the third 6. The tusk had flattened into an ellipse about 9x5 inches near the butt, and 6 or 7 feet long.

A second discovery was made about three feet underground in ditching close to the Pere Marquette shaft No. 2 in East Saginaw, by Wm. Leamon, who brought a tooth to Wm. Richter, the well-known taxidermist of Saginaw,[4] who identified it as that of a mammoth. It was about 25 feet above lake, 2½ to 3 feet down, and in size 11x5 inches, and in pretty good condition, though the base was gone.

Not far off in Tittabawassee township, I found pieces of a tusk among the farmers, said to have come from one cut in a ditch on Sec. 20 near the course of the Parker swamp drain about one-fourth mile north of the south line of the section. Mr. Richter also says that three feet of the end of the tusk, the lower jaw and rib of a mastodon were found in a kind of quicksand six feet underground in digging a tile ditch on the Willis farm.

[1] Bela Hubbard's report; mastodon in the western part of Macomb county, and on the Paw Paw river in Berrien county.

[2] Page 132. Mastodon at Green Oak, Livingston county, and Plymouth, Wayne county. Mammoth in the northern part of Jackson county, and in Macomb.

[3] For free pamphlet describing the difference, write F. A. Lucas, National Museum.

[4] Saginaw Courier-Herald, Oct. 31, 1901.

Other recent occurrences noted are:

In a swamp in ditching Stafford's farm, Church[5] near Hillsdale, a large part of mastodon acquired by the National Museum.

Olivet,[6] exhumed and acquired by the college, eight teeth and a large number of bones, the largest being 38 inches long and 25 inches around.

Four miles west of Dorr[7] by Frank Fleser and others, a jaw bone 8 inches wide, 22 inches long, with several teeth, one being 7 inches from crown to root and 10 inches in circumference.

Clinton, Lenawee county, by P. B. Gragg, "several teeth and bones."

Mr. W. F. Cooper also found traces of one of these animals in Frankenlust.

According to the notes of Mr. W. F. Cooper (1900, p. 16), a mastodon was found near the southwest corner of Sec. 3, Williams township, Bay county, about 621 A. T., and was sent to Ypsilanti, including a fragment of a tusk, but little curved, 8 feet 9 inches long, a femur and thigh socket 9½ inches across, one vertebra 12 inches high from top to bottom, and one tooth. Found in a small, deep hole of mucky soil which had been a bog hole until drained. The skeleton was buried three feet below the surface, according to Mr. John C. Rowden, to whom the Survey is indebted for this information.

Finally, relics of a mastodon and his meal have recently been found near Niles in the Bakertown marsh southwest of Buchanan, associated with marl, the shells of which have been described by B. Walker.[8]

Now that the presence of mammoth and mastodon in the State are well established, the point of interest to me in these finds is to see how near to the present lake level, i. e., to how recent a date these animals survived. If these finds in Bay and Saginaw counties are of animals mired in place,—it is hardly likely that so many fragments would be found far from shore, and they seem to be in hollows and miry places,—then it is certain that the animals survived at least until the lakes were down to about 30 feet of their present level in that region. This means probably not more than a very few thousand years ago, and of course possibly a much more recent date.

[5] Saginaw Courier-Herald, June 9, 1901.
[6] Sept. 29, 1900.
[7] July 5.
[8] Nautilus, March, 1898, Vol. XI, p. 121; September, 1899, p. 55. Details have been kindly furnished by Wm. Hilles Smith. E. H. Crane of Kalamazoo has the bones.

UPPER PENINSULA.

In connection with limestones and prospects for gas and oil we have given some facts regarding the eastern end of the upper peninsula, a region that has been almost neglected since the publication of Vol. I.

In the section in regard to temperatures we have given some points relative to underground temperatures in the iron and copper mines.

Prof. C. R. Van Hise has published, in the last annual report of the United States Geological Survey (Twenty-first, Part III, p. 313), an admirably lucid summary of their investigations on the iron ranges. There is, however, as it seems, still room for work to be done in the iron country, and especially for the preparation of a map, on as large a scale as can be conveniently handled, to cover the whole upper peninsula and summarize and supplement the work of the United States Geological Survey, and more carefully adapt it to the section lines.

There is yet other work. Outlines of the iron ranges not covered by their detailed maps should be worked up, and the lines of magnetic attraction, which are a key to the structure of the iron-bearing series, should be and can be followed under the surrounding mantle of sedimentaries. There are, however, two men so pre-eminently qualified for this work that it would be a pity to set anyone else at work so long as there is any chance that one of them may be had,—H. L. Smyth, in charge of the Mining Department of Harvard University, who has superintended some important private geological surveys as well as been connected with the United States work, and A. E. Seaman, in charge of Geology in the College of Mines, who has studied these rocks in the field every summer for nearly fifteen years.

Both of these men, however, deserve much better pay, and receive it, for that class of work, than it is easy to provide from our appropriation without dropping practically everything else. An extra appropriation for iron country work, such as I suggested to the last legislature, of $4,784, might easily pay for itself in taxes in a few years, if thereby new mining districts were opened up.

In the copper country, Dr. Hubbard and Mr. Savicki have continued to collect data.

Two other matters of somewhat curious interest may be referred to here that those interested may not overlook them.

Prof. G. A. Koenig of the College of Mines has continued his researches on the basic arsenides of copper, of which a series occur on Keweenaw Point, to wit:

Cu_x	As_1	
3	1	Keweenawite (+ 20 per cent Ni).
4	1	Domeykite (+ Ni is Mohawkite).
5	1	Ledouxite.
6	1	
7	1	Algodonite.
9	1	Whitneyite.

Papers will be found in the current American Journal of Science and Proceedings of the Lake Superior Mining Institute.

The second point is the divergence of the plumb bobs in the Tamarack shaft. In planning connections of Tamarack shaft No. 5 with the rest of the mine plumb bobs were dropped down the shaft 4250 feet long and 17.58 feet apart at the surface. They proved to be 17.65 feet apart at the bottom. They were composed of No. 24 piano wire and had 50-pound steel bobs at the end.

In No. 2 shaft the experiment was repeated with lead bobs, and the divergence was from 12.6 to 12.7 feet.[1] Some discussion has sprung up as to the cause, and President McNair of the College of Mines will undertake further experiments.[2]

The fact is that these deep shafts furnish the finest chance in the world for experiments in geophysics, and so far as the exigencies of mining permit they should be used. This is a work which we should either do or, better yet, cooperate with the College of Mines in doing.

One subject, that of the extent to which the temperature of the surrounding rock may be affected by the ventilation of the mine, is a very important question, practically and scientifically, to solve which business and scientific men of various kinds should work hand in hand.

[1] See Portage Lake Mining Gazette, March 28, 1901, for description of shaft and section down to C. & H. conglomerate; Oct. 8, description of effect. Letter of R. M. M., Oct. 13, Oct. 15, Dec. 29; Prof. W. H. Hallock, Jan. 16; C. B., Oct. 16, etc., for explanations.

[2] Pres. McNair's results have been published while this report is going through the press. See the Portage Lake Mining Gazette for May 1, 1902, and Engineering and Mining Journal for April 26, 1902. The essential result is that ventilation currents are the dominant factor in the effect observed.

RELATIONS OF THE GEOLOGICAL SURVEY.

AGRICULTURAL COLLEGE.

The close relations into which I have been brought with the Agricultural College, to which I referred last year, have been continued and have been a source of sincere satisfaction. The work of the survey is such that questions continually arise which are fit subjects for advanced students to investigate and report on by thesis, such as the composition and character of coal, of water, the connection between botanical distribution and soils and we have been able to furnish advice and in some cases a moderate amount of financial assistance to such students.

There is also a demand for chemical investigation of various raw materials and ores. It seems to me that when the results of the test will be mainly to the benefit of the land owner the one benefited should pay, but in other cases, as has been recognized in the question of public water supplies, the State has recognized the public interest in the matter. Many state geological surveys employ a chemist constantly but it has seemed to me wiser, in view of the fact that the State already supports five or more chemical laboratories, to save expense of equipment by asking their assistance, under such conditions as may be found acceptable, and in this I have been met more than half way by Prof. F. S. Kedzie, and I have him most particularly to thank for much uncompensated work, in addition to that for which we were able to pay. I have also to thank Dr. V. C. Vaughan and A. O. Campbell of the University, Dr. G. A. Koenig of the College of Mines and numerous private chemists, whose names will be found appended to the analyses they have contributed for additions to our knowledge of the chemical relations of our raw materials.

While, however, a certain amount of a certain grade of chemical work can be done by students in the course of their studies, and in return for material supplied by the survey, and not a few questions received at the Agricultural College have been turned over to me to answer, it is only fair and proper that the survey should furnish adequate pay for accurate and elaborate analytic work, and there are a number of lines of investigation for which I should be glad to have larger resources.

A careful and systematic examination of our brines for the potash might be of great technical value for the State. A series of analyses to test Van Hise's theory of the origin of our ore deposits would be of scientific interest, and samples of clay, etc., continually come of interest enough to warrant more extensive investigation. Some of these investigations might be undertaken jointly. The search for nickel to which I have referred is rather a subject for thesis investigation.

I have also Messrs. Beal, R. C. Kedzie, Barrows, Vedder, Wheeler, and Longyear to thank for scientific assistance.

My relations with the experiment station work have continued of a mutually helpful character. As it does not refer to my own work but that of Prof. W. H. Sherzer[1] I beg leave to quote the following letter:

Experiment Station, Agricultural College, Mich., December 7, 1901.

My Dear Sir—It gives me great pleasure to report to you an incident which casts a side light of value of your most excellent work to the practical, every-day industries of Michigan. I was recently asked by certain parties interested in sugar factories and seeking new sites for factories, to make a survey of Monroe county and find its adaptability to this industry. On inquiry I found the work of Prof. Sherzer on the soils of that part of the State. With the map from his work in hand I began the survey. After working two days to verify his map, I found it so correct, even in minute detail, that I stopped my work at once and sent in his map as my report, giving, of course, proper credit to your office. That map was final authority in the hands of the syndicate. Later I have worked elsewhere in the State and have found that you have preceded me and done the work so well that I have simply referred the people interested to your investigations, and they have gladly accepted them. I congratulate you, therefore, in having been of signal benefit to our nascent agricultural industry.

Yours respectfully,
C. D. SMITH, Director.

COLLEGE OF MINES.

I was very glad to let them have the services of our Mr. Cooper to collect samples of the materials of the Lower Peninsula, particularly those of economic value, for the collections which they are preparing to loan to the high schools, but they paid his salary and expenses when thus engaged. But now President McNair has suggested to me the possibility of co-operation in the study of some of the deep shafts of the copper mines. These, unique in depth and in other respects, offer an opportunity for the study of the diffusion of the heat, electricity, magnetism and gravity of the earth which should not be neglected, in which study we ought to work hand in hand with the College of Mines, as the results would be a part of a geological survey of the State. The only question is how much can we do with our money and our other calls.

Another point in our relations with the College of Mines is by no means so agreeable to take up.

As you will remember, the building of the Geological Survey has stood for some eight years upon land belonging to the College of Mines, which they reserved the right to use if needful. I append the vote of the Board of Control of the College of Mines upon the subject which was accepted by your Board.[2] I presume that it is true that at the time of the location none foresaw the rapid growth of the Mining School or supposed that the necessity of removal would be anything but a very remote contingency.

After some correspondence, which was laid before you, and informal conversation with the presidents of the Board of Control and the College, in July, 1901, I met with the Board. I found that they recognized the

[1] On Monroe County, Vol. VII, Part I.

[2] A meeting of the board of control of the Michigan Mining School, duly called, was held at the office of the chairman on the 6th day of October, 1893, at 2 o'clock p. m. There were present: Jay A. Hubbell, chairman; Alfred Kidder, P. C. F. West, T. B. Dunstan.

The following resolution was offered and on motion was duly carried and adopted, viz.:

That the Board of Geological Survey for the State of Michigan be permitted to erect a suitable building on the east side of the Michigan Mining School property for the Geological Survey, on a piece of ground to be designated by the executive committee of the board of control, and to occupy the same free of rent for the purpose of carrying on said survey, but for no other purpose: said ground occupied by said building to be under the general management of the board of control of the Mining School. The board of control reserving the right if at any time the ground occupied by said building should in their judgment be needed for the use of the Mining School, to remove the structure to some other part of the grounds: the said Geological Survey to occupy said ground on which such building shall be erected as tenants at will of the board of control of the Michigan Mining School.

embarrassing position in which we were placed, for we were only notified when it was too late to obtain anything from the Legislature, as well as their obligations to provide for the removal and a new site for the Geological Survey building upon their grounds. But I found a considerable difference of opinion as to where that site should be, and I saw that not only would the site be neither so convenient nor so dignified as the present but it would not be permanent. The new building for the College of Mines might mean a new move and it was a question whether your Board could compel the Board of Control to pay the expenses of moving each time. There was at least a chance of legal controversy, the expenses of both sides of which, as well as of the removal, would in any case fall upon the taxpayers of the State. Of course, too, every remove meant a certain amount of damage to Survey property and interruption of the scientific work of the Survey. Mr. Savicki has done little but look after things for the past few months.

I therefore proposed to the Board of Control that if they would find the balance I would, personally, subscribe $100 for a lot of land upon the slope over against the grounds of the College, upon which to place the building where it might permanently rest. In this they met me more than half way leaving me but $75 to pay. Besides the members of the Board of Control, President McNair and Mr. Charlton, the architect, contributed and a lot was obtained, which was marked on the plat at $350, through the good offices of H. S. Goodell for $250. The removal has, I regret to say, dragged out so that even today the building is not completely on its new foundations, and it will be impossible to give the data regarding publications issued and received which have annually been included in this report I shall try to supply the omission next year. It would be a very wise thing, in view of the ever accumulating mass of valuable material, to veneer the building with brick, now that it is no longer so isolated, and at the same time provide for enlargement.

The organizers of the Geological Survey expressed their sense of the close relation in which it stood to the educational interests of the State by making the Superintendent of Public Instruction a member of the Board. The work should stand in close relation with the colleges as well as to the business interests of the State. In regard to its relation to the secondary schools, you have instructed me to furnish the reports gratis to teachers, and a good proportion have gone that way. The demand for Prof. Sherzer's report on Monroe county has been especially lively.

In regard to the question sometimes agitated as to the introduction of geology into the high schools, my opinion is strongly against any teaching of geology as such by itself, and a "fourteen weeks course in geology" is more of a burden than a benefit. Geology, as the life history of the earth as a whole, presumes an acquaintance with most other sciences, and if introduced too early can only lead to half grounded knowledge. But there are several other matters of study often neglected unless introduced under geology, which might and should receive greater attention. Mineralogy, including a recognition by sight or simple tests of the commoner minerals and rocks, exercises the same powers of observation and discrimination as botany, leads also to open air excursions, and gives a freer vent to that instinct for collecting, which finds much less scientific bent in stamp collecting. It is quite as practical as botany on the whole, and

Prof. Gregory of our force, who is also superintendent of schools at East Tawas, has found it is much more attractive to boys. One of the great problems in high schools is to keep the boys in school as long as their sisters. It is not normal nor desirable that the women should be better educated than the men. It is a matter of experience that mineralogy appeals to boys as botany does not. It seems to me that in our county reports or in special bulletins we should assist the local teachers in the local mineralogy. The collections made for them by the College of Mines to which I have referred will be of interest in this matter.

Another subject where the Survey can help the local teacher and should do still more in the future, is in the study of geography, especially physical geography. Between geography properly taught and geology there can be no sharp line. Both should be taught by beginning with facts of common experience to the school. That is to say, the scholars should begin with the map, the raw materials, the river, lakes and physical geography of their own neighborhood. In this study our county reports can be of material assistance, and such men as Messrs. Davis, Sherzer, Gordon, and Gregory, experienced and successful teachers, should be employed in teachers' institutes to inform others in the art which they have learned of making real and interesting the study of geography by the use of local facts.

OTHER SOCIETIES.

I have tried to keep the Michigan Academy of Science, the Michigan Engineering Society,[1] and the Lake Superior Mining Institute informed and interested in our work, as their membership forms the constituency who will most naturally appreciate our work, and brief papers have been presented before these bodies.

A scientific subject of most practical bearing is that of forestry. Not merely the question of keeping up a supply of lumber for those industries which are so weighty a part of the business life of the State is concerned. Room for the manly sport of hunting and fishing, and the preservation of pure sources of civic water supply and of constant water power are also concerned, and perhaps the whole question of climate as well. And in planning forest reserves it is essential that such geological studies as Livingston's and McLouth's, Taylor's and Leverett's, here presented should precede, in order to have intelligent action. The Geological Survey should co-operate and I personally made one trip about Roscommon with the State Land Commissioner and other interested parties and have always tried to give him prompt information. But the amount of work which ought to be done soon is far beyond our present means to co-operate. I would however earnestly recommend that no land belonging to the State either directly or to any one of its great schools be sold until it has been carefully examined, with due regard not merely to the surface but also to the depth of that surface and the general structure and water supply, and availability for farming or other uses.

[1] Which body passed a vote of thanks for what you have done toward topographic survey.

A very detailed map of the immediate neighborhood of Ann Arbor, may be issued separately.

In regard to the deep seated rocks, the same arrangement by which we have confined ourselves to the copper bearing rocks, and the workers under Van Hise to the iron bearing rocks has been continued. But as the U. S. Survey has nearly completed its work on the iron bearing rocks we ought to begin work on that district again. C. R. Van Hise in charge has just issued, as I have mentioned, an admirably clear resumé of his results and his theory of the origin of the iron ore deposits. The terms upon which the publications of the Survey are to be obtained vary, and enquiry should be made of the director of the U. S. Geological Survey at Washington, D. C.

In regard to the paleontological work, I trust that arrangements may be made so that for detailed correlation and study of parallel forms we may have the assistance of the U. S. Survey, so that descriptions of new species, and comparisons with fossils of other states and such matter of interest to science generally, may be given their wide circulation, and that type specimens may be on deposit in the National Museum, while we may have abundant duplicates for local use and distribution, and illustrations, and stratigraphic and other matter, peculiarly of State interest may also appear in our reports.

---

wherever such primary control is deficient it shall be supplemented by the Co-operative Topographic Survey.

4. The survey shall be executed in a manner sufficiently elaborate to prepare a map upon a scale of 1:125,000, exhibiting the hydrography including the courses of the principal drains, hypsography and public culture including the location of farm houses and roads, and all town and county boundary lines and township and sections of land survey lines, as marked upon the ground at the time of its completion, in form similar to the sheets already completed in other states. The preliminary field maps shall be on such scale as the director of the United States Geological Survey may select to secure accuracy in the construction of the final map.

5. The hypsography shall be shown by contour lines with vertical intervals of 20 feet.

6. The heights of important points shall be determined and at least one permanent bench mark established in each township or equivalent area and a list of elevations and descriptions of them furnished to the Board of Geological Survey.

7. The outlines of wooded areas shall be represented upon proofs of the engraved map to be furnished the Board of Geological Survey.

8. For convenience the United States Geological Survey shall, during the progress of the field work, pay the salaries of the permanent employes engaged thereon, while the traveling, subsistence and field expenses shall be paid for the same time by the State. For office work on the map the salaries shall be divided between the two agreeing parties in such a way as to equalize all expenses, provided that the total cost to the State of Michigan of the field and office work shall not be more than two thousand dollars ($2,000), except as may be hereafter agreed, and provided that the United States Geological Survey shall expend an equal amount upon the same work.

9. During the progress of the work free access to the field sheets and records of the topographers and draughtsmen shall be afforded the State Geologist or his representative for examination and criticism: and should the said State Geologist deem that the work is not being executed in a satisfactory manner, then he may, on formal notice, terminate this agreement.

10. The resulting map shall recognize the co-operation of the State Board of Geological Survey of Michigan.

11. When the work is completed, the Board of Geological Survey of the State of Michigan shall be furnished by the United States Geological Survey with photographic copies of the manuscript sheets: and when the engraving is completed, and at all times thereafter when desired, it shall be furnished by the said Survey with transfers from the copper plates of the map for use in printing editions of said maps.

12. Field parties shall expend their own money and take duplicate receipted vouchers. These to be examined and approved by the director of the United States Geological Survey, and those provided by section 8 to be forwarded to the State Geologist and paid by the Auditor General by draft upon Detroit. The director of the United States Geological Survey is to make a monthly statement of account to the State Geologist showing expenses by United States, as well as vouchers furnished to the State. Expenses by both sides to be finally balanced not later than September 1, 1902.

Lansing, Mich., August, 1901. ALFRED C. LANE, State Geologist.

Washington, D. C., August, 1901. C. D. WALCOTT, Director of the U. S. Geological Survey.

money, which with your permission I employed in preparing, in accordance with a long cherished plan, a sample sheet of a topographic map such as the U. S. is prepared to execute in co-operation with the State. The advantages of such a map have been repeatedly urged,[1] and it seemed to me that by thus preparing a sample sheet where it would be of use to the great number of students at the University and Normal College, the growth of a general public sentiment which would appreciate such maps would be helped. It is obvious also that for all our geologic work, mapping soils, forests, rocks, borings, etc., a good topographic map is a prerequisite to accurate work and that if we can get the U. S. Survey to bear half of the expense of the same we are so much ahead.

Accordingly the subjoined contract with the U. S. Geological Survey was prepared[2] under the provisions of which the following work has been done and expenses incurred.

United States Geological Survey, Washington, D. C., December 31, 1901.

Dear Sir—Referring to my formal agreement with you for the execution of a co-operative topographic survey of a district in the vicinity of Ann Arbor, Michigan, by the terms of which agreement you contributed $2,000, provided that this Survey would expend an equal amount upon the same work, I have to make the following report:

Immediately following the signing of the agreement Mr. John H. Renshawe, geographer, in charge of the central section of topography, was authorized to begin the preparation of plans for field work. Mr. George T. Hawkins, topographer, began work on the horizontal control for the district on August 21 and continued until September 3, during which time he ran 116 miles of primary traverse, starting at the triangulation station of the U. S. Lake Survey at Tecumseh, tying with the astronomic position at Ann Arbor, thence to Detroit, where he connected with the primary position of the U. S. Lake Survey.

Mr. Robert Muldrow, topographer, was placed in charge of the topographic field work, which was commenced September 2 and was prosecuted without interruption until the end of November, during which time 292 miles of primary spirits levels were run, based upon the precise datum established by the U. S. Coast and Geodetic Survey at Gibraltar, and 110 square miles of topography were completed on a scale of 1 mile to the inch, with a contour interval of 20 feet. The topographic work completed lies in Tps. 1 to 3 S. inclusive, R. 6 E. The field work was necessarily slow on account of the complicated glacial forms in the vicinity of Ann Arbor.

From your contribution there has been expended in field work, as shown by the vouchers which have been sent you, $1,012.65, against which this Survey has expended from its own funds for the permanent salaries of Messrs. Hawkins and Muldrow, and for traveling expenses to and from the field, the amount of $601.41.

Field work will be resumed as soon as the weather will permit in the early spring, when the balance of your contribution will be expended and the work continued until the district is completed. It is expected that the work will be finished in the early fall and that the sheet will be published about a year from this time.

Very respectfully,
H. C. RIZER, Acting Director.

---

[1] By the Michigan Academy, Engineering Society, Prof. Russell, and others:

SENATE OF THE UNITED STATES.
Committee on the District of Columbia,
Washington, D. C., February 18, 1901.

My Dear Sir—I have your letter of February 11, in regard to a topographic survey of the State of Michigan, the expense to be met partly by the State and the work to be done by the United States Geological Survey. As you surmise, I am familiar with the topographic maps issued according to such arrangements. They are valuable beyond any price that can be put upon them, and the State of Michigan more than almost any other state needs just such a map. The provision that the United States shall share in this expense is an unusually liberal one on the part of the general government, and in my judgment there should be no hesitation on the part of the State of Michigan to take advantage of it.

Yours very truly,
JAMES M. McMILLAN.

Prof. Alfred C. Lane, State Geologist, Lansing, Mich.

[2] Agreement between the State Geologist and the director of the United States Geological Survey for the execution of a co-operative topographic survey of one thirty-minute quadrangle in the State of Michigan:

1. The preparation of the map shall be under the supervision of the director of the United States Geological Survey, who shall determine the methods of survey and map construction.

2. The quadrangle to be surveyed under this agreement shall be that between latitude 40° and latitude 40°30′ and longitude 83°30′ and longitude 84°.

3. The work shall be based upon the triangulation of the United States Lake Survey, and

WORK.

Upon the completion of Vol. VIII, and the Annual Report, some county reports should be ready for publication as Vol. IX. I should like to have a group of counties about Saginaw bay included. Until we are better caught up with the preparation and publication of reports on counties of which the field work is done, I doubt the wisdom of pushing county work much with this one exception, that Prof. Sherzer has returned and will be unusually able to take up field work the next few months. In connection with his very successful and valuable Monroe county report he has already done part of Wayne county. The sinking of the shaft of the Michigan Rock Salt Co. will give an unique opportunity, and it is time that we rounded up the numerous well records which we have collected along the Detroit river. Therefore I would recommend that Prof. Sherzer be employed to prepare a report on Wayne county similar to that which he has prepared on Monroe county.

Peat has excited considerable interest of late and I have had numerous inquiries regarding it. It seems to me that where we have so much bituminous coal it is not likely to be so important an industry as in Canada. But the resources of the State are very great, and especially in the Upper Peninsula, where there is a dearth of fuel, it might be that the use of peat which was tried years ago, would not only find a domestic market, but be the means of utilizing vast quantities of low grade ores. I would recommend that a report on peat be prepared.

The production of gypsum in the State is not keeping pace with that in other states, nor is it commensurate with the wealth of our natural materials. The industry is in a few hands which are perhaps not anxious to see it grow beyond their grasp. We have had an opportunity to have a report prepared by an exceptionally competent man, and I would like to see one undertaken if we can afford it.

We ought also to prepare a general geological map of the Upper Peninsula on such a scale as to show the sections and in corresponding geological detail. And we ought really also now to take up a general review of the iron country, filling up various gaps left by the U. S. Survey, adapting their work more closely to the property lines, putting it into more portable and economic shape, and extending the surveys of lines of magnetic variation and the study of the structure as far as they can be extended beneath the mantle of the Potsdam sandstone. But in order to do anything worth while in this direction we must have more money. My friend and classmate, Prof. Smyth, head of the Mining Department of Harvard University, would be an admirable man to take charge of this work for us, as he has already conducted important private geological surveys for some of the larger corporations and I think I could persuade him to do it, if there were enough money available to do anything worth while in any reasonable time.

I see no reason for large expenditure in gathering up, correlating and tieing the records of the recent surveys in the copper country. By another year, however, we ought to do much more work in the northern peninsula.

FINANCIAL.

Owing to the confusion existing in the Houghton office which is not yet plastered it is not possible to give as usual just the exact statistics of distribution of our reports. Of Vol. VI there are very few left. Of Vols. V and VII there is just a comfortable supply. The main demand in Vol. VII has been for the Monroe county report.

The expenses up to July 1 were as follows:

	Salary.	Field.	Office.	Total.
July	$634 87	$112 85	$57 82	$805 54
August	667 73	155 80	68 54	892 07
September	656 68	127 23	37 96	821 87
October	563 49	215 57	102 94	882 00
November	426 02	82 53	133 60	642 15
December	458 50	79 59	15 95	554 04
January	462 20	20 15	64 16	546 51
February	445 60	65 29	24 00	534 89
March	454 80	30 38	37 48	530 06
April	460 40	4 85	51 36	511 01
May	442 30	42 48	27 81	530 69
June	.....	32 18	114 06	588 54
Belated vouchers	.....	58 98	40 76	99 74
	.....	50 00	10 29	60 29
Total	$6,134 79	$1,077 88	$786 73	$7,999 40

Of our appropriation for the current fiscal year $4,338.57 has been spent, of which $1,012.65 has been spent through the U. S. Survey for the topographic survey about Ann Arbor. The balance of the year there will be little chance to do anything but regular routine work, getting out the annual report, Vol. VIII, part III on Marl and Cement materials, paying for our share of the work around Ann Arbor, and preparing the county report for the ordinary office and salary list cannot fall below $425 a month.

The appropriation for next year beginning July 1 may be divided as follows provisionally:

Fixed salaries and office expenses	$5,300	
Continuance of work—		
Report of borings	60	
Expenses on reports and sundries	250	
Co-operation in topographic survey	200	
Arenac county work continued	200	
Bay county work continued	320	
Tuscola county	300	
Field expenses of State Geologist	270	
Limestone work continued (Grabau)	200	
U. P. field work	300	
New work—		
Wayne county (Sherzer)	600	
		$8,000
Desirable but apparently not feasible—		
Peat	$200	
Gypsum report	550	
Co-operation in topographic survey	3,000	
Iron country surveys, not less than	4,784	
		$8,534

APPENDIX.

REPORTS OF C. H. GORDON ON THE PORT HURON OIL FIELD, AND THE EROSION OF THE SHORE NORTH OF PORT HURON.

THE PORT HURON OIL FIELD.

C. H. GORDON.

INTRODUCTION.

The special investigations upon which this report is based were made under the direction of State Geologist, A. C. Lane, during the summer of 1901. A considerable amount of data, however, relative to the stratigraphical relations of the region had been obtained by the author while prosecuting field work for the report on Sanilac county in 1896.

The presence of oil in rocks underlying Port Huron has been known many years but until recently it has not been obtained in sufficient quantity to be of commercial importance. The occurrence of oil in Western Canada was described in the reports of the Geological Survey of Canada nearly sixty years ago and "although at that time no use for the substance was known in Canada, except as a supposed remedy for rheumatism and for spavin for horses, Sir William Logan, the director of the Survey, with characteristic sagacity, foresaw that it might some day become of value in this country, as it had long ago proved to be in the East."[1]

In 1860, following the introduction into the province of illuminating oils distilled from coal and shale, interest in the subject was renewed and attention was again called to the existence of natural oil and "gum-beds" in the county of Lambton in the west and Gaspè in the east. In the winter of 1860 and 1861 several great flowing wells were struck at a place in Enniskillen township to which the name of Oil Springs was given. "The oil escaped so rapidly that many thousands of barrels were lost before it could be controlled, or the means provided for saving it." In these wells the oil was found in the upper part of the Corniferous limestone beds at a depth of 260 feet from the surface. As development went on some additional flowing wells were obtained but one by one they were all reduced to pumping wells and some gave out altogether.

The Oil Spring area is said, by Robert Bell, acting Director of the Canadian Geological Survey, to whom we are indebted for information concerning the Canadian field, to be of small extent. It lies between the village of the same name and the south line of Enniskillen township. The oil field of Petrolia begins a little to the southeast of the center of Enniskillen and extends in a west-northwesterly course parallel with that of Oil Springs nearly to the center of Sarnia township, a distance of twelve

[1] R. Bell, Transactions Royal Society, Canada, 1887.

or thirteen miles. It has a breadth of two to three miles, the center third being most productive.

Oil operations went on in this region with varying activity until 1886 when renewed impetus was given to the enterprise by the discovery of a third oil bearing area in Euphemia township parallel with the longer axes of the Petrolia and Oil Springs areas.

The interest excited by the Euphemia discovery led to the sinking of several wells at Port Huron in 1886 and 1887. Prior to this some wells had been put down along the river with the expectation of finding gas. While nearly all of these were successful in finding gas in the upper part of the Dundee limestone at about 500 feet from the surface the pressure was too weak to make them of commercial importance and none ever went beyond the "burning well" stage. In 1886, C. A. Bailey undertook a determined search for oil, putting down a number of wells. Well No. 1 was located 500 N., 1000 W., Sec. 9, T. 6 N., R. 17 E., and the two others are supposed to have been in close proximity to these. The records of these wells are published in Vol. V, Michigan Geological Reports. These records show that the oil rock (Dundee) was reached at 543, 545 and 572 feet respectively. A small amount of both oil and gas was obtained from these wells but the further attempt to develop the area was abandoned. The surface elevation of this locality is about 605 feet A. T. or 25 feet above the level of Lake Huron.

In 1887, F. L. Wells sunk a well to a depth of 1,685 feet stopping in the Salina formation. This well is located on the bank of Black River, opposite Kern's Brewery, about five feet above the level of the lake (585 A. T.). The oil formation (Dundee) was reached at a depth of 515 feet with "show of oil and gas."*

Following this period of activity, interest in the oil question subsided until 1898 when G. B. Stock, who had formerly operated in the Canadian field organized the Michigan Development Company and began operations on the Goodrich property in close proximity to the Bailey wells. The amount of oil obtained was considered sufficient to pay for operating and additional wells were sunk until now sixteen wells are scattered over that area, most of which are pumping. In addition to these wells, Mr. Stock put down several wells in other places north and west of Port Huron in the hopes of finding a greater supply of the fluid. His example has inspired other prospectors with the hope of successful ventures and several other attempts have been made though as yet with little success.

L. W. Holt representing outside capitalists began operations on the Sweitzer property about three miles north of the Stock wells, and a local company began on a well at Valley Center, thirty miles northwest of Port Huron during the winter of 1898 and 1899.

Sources of Oil.—The presence of oil in a formation depends rather upon the structure and attitude than upon the nature of the rocks. No geological horizon can be regarded as distinctively an oil horizon. In northwestern Ohio and Indiana the Trenton is the source of supply of the oil and gas of that region while in Pennsylvania, West Virginia, New York and Canada the Devonian is the great oil bearing horizon. In Texas, while both oil and gas are known to exist in the Carboniferous and in the Cretaceous, in a few localities of the latter only is there sufficient quantities to be of commercial value. Of these the Corsicana field is the

* See Vol. V and p. 254 of this report.

most important. In the Beaumont field where the richest oil strikes of the last quarter century have been made the oil is found in the middle of the Tertiary, probably in Miocene rocks. In California the oil comes from rocks ranging from Neocene to Miocene, and in Galicia (Austria-Hungary) the oil bearing rocks range in age from Cretaceous to Miocene. The Russian oil is obtained from Lower Miocene.

According to R. Bell[2] the anticlinal theory in connection with the accumulation of gas and petroleum originated with Dr. T. Sterry Hunt, who announced it in a lecture published in 1861. According to this theory these lighter fluids following the upward slopes of strata accumulate in largest quantity under the summit of the dome. Naturally the gas being lightest takes the highest place, the oil next while the water below presses hard upon them. When the summit of the dome is tapped gas, if present, will escape first followed by the oil then water. The more extensive the anticlinal as to breadth or depth the greater will be the accumulation of gas and oil and hence anticlinals of small extent are not likely to prove profitable sources of supply of these products. Other necessary conditions for the accumulation of oil are, (1) deeply seated petroleum bearing rocks of considerable volume, (2) a stratum of porous, fissured or channelled rock for storing the accumulated oil and (3) an impervious layer of argillaceous rock overlying the petroleum bed to prevent the escape of the oil.

It is obvious that the oil is not likely to be found at all points along the crest of an anticlinal but will be concentrated in the domes or elevations caused by secondary upheavals.

Origin of Petroleum.[3]—Much diversity of opinion exists among those who have written upon the origin of petroleum. Two principal views are held, the first being that it has arisen from chemical and physical changes in inorganic material and hence termed the *inorganic theory.* This view is advocated by Berthelot, Humboldt, Mendelejeff, Moquenne, Byasson, Cloez, Russ, Sololoff, Coquand, Grabowski, Hitchcock and others. The second is termed the *organic theory* and holds that the oil has arisen through the spontaneous distillation of animal and vegetable remains at low temperature, with or without pressure. This view is supported by such men as T. Sterry Hunt, Lesley, Orton, Dana, Leconte, Hoefer, Wall, Daubree, Ochsenius,[4] Newberry, Wall, Peckham, Credner, Warren, Storer, Engler, Zoloziecki, Sickenberger, Von Kobell, Watson, Smith, Von Buch, Bertels, Zincken, Paul, Tietze, C. Phillips, Redwood, White, Whitney, Binney, Hatchett, etc.

The inorganic origin of petroleum is receiving less and less support as the field of chemical investigation is extended while the weight of opinion inclines more and more to the view that this substance is derived from the decomposition of animal and vegetable remains. W. B. Phillips[5] in his recently published bulletin on Texas petroleum reports the results of an investigation tending to show the connection of diatoms with oil production and suggests that these low forms of life may have played an important part in the formation of oil deposits.[6]

[2] Petroleum Field of Ontario, Transaction Royal Society of Canada, Vol. V., p. 103.
[3] See Vol. V, Part II, introduction by L. L. Hubbard.
[4] Chemiker Zeitung, 1887, 11, No. 56; 1891, 15, No. 53.
[5] W. B. Phillips. Texas Petroleum, Bulletin University of Texas, 5.
[6] For fuller discussion of this subject see above Bulletin, also Vol. V, Michigan Geological Survey, Part II, p. xix.

GEOLOGICAL RELATIONS OF THE NORTHERN OIL FIELD.

Investigations have shown that the Ohio and Canadian gas and oil deposits occur on the course of the great Cincinnati anticlinal which extends northward from Kentucky through Ohio and western Ontario bearing north-northeastward, from about Point Pelee on Lake Erie, through the counties of Essex, Bothwell and Lambton. It reaches Lake Huron at about Kettle Point and continues under the lake parallel with the eastern shore to a point opposite Southampton, when, turning a little more to the northeast, it crosses the Indian peninsula parallel to another anticlinal that seems to run through Saginaw bay and the gap between the extremity of this peninsula and Grand Manitoulin island.[7] Prof. Edward Orton's investigations on the gas and oil discoveries in Ohio led him to the conclusion that the Trenton limestone received its low arched form along the Cincinnati anticline in that region before the succeeding formation was deposited upon it, while the stratigraphical relations in the Petrolia and Port Huron fields indicates either that a further upward movement took place after the formation of the Dundee limestone and before the deposition of the Traverse shales upon it, or that in this region there was an extensive coral island formation. It is quite possible that both of these agencies combined to give these beds the structure and attitude necessary to constitute them a reservoir for the petroleum originating in lower lying formations.

While the Cincinnati anticlinal is, in general, a gentle swell of great breadth there occur within its area many minor folds and undulations running both parallel with, and transverse to, the general direction of the main axis.

The investigations in western Ontario have shown the existence of a number of these minor transverse folds having two principal courses one about east and west and the other northwest. The fold in the Dundee, shown on Plate IX, at Port Huron is in direct line with the general trend of the undulations in the Enniskillen field and evidently constitutes a part of the same series, while seemingly another branching off from the main axis farther south passes through Mount Clemens.

THE CANADIAN OIL FIELD.

The obvious connection of the Port Huron field with the Lambton county oil area makes it desirable to preface a description of the former with a brief account of some of the wells adjoining Port Huron on the Canadian side.[8]

"The oil of Lambton county is, in the main, obtained from two distinct pools known as the Oil Springs and Petrolia fields, both in the township of Enniskillen. The larger of the two—the Petrolia field—with an approximate area of twenty-six square miles, extends west-northwest about nine miles and east-southeast about four miles from the village of Petrolia; while the Oil Springs field covers two square miles and includes the southeastern part of the village of Oil Springs. The pools are divided by a very distinct synclinal structure, the upper beds of the Hamilton

[7] R. Bell. Transaction Royal Society, Canada. Vol. V. p. 105.
[8] For this information we are indebted to H. P. H. Brummell's Report on Natural Gas and Petroleum in Ontario. Geological Survey of Canada, 1892.

"(Traverse)" being overlain by the black pyroschists of the Portage "(Antrim)" formation; these black shales have at Oil City, between Petrolia and Oil Springs a thickness of forty feet immediately beneath which is found the upper limestones of the Hamilton (Traverse) series.

"The black shale is absent at Petrolia and Oil Springs, the surface rock underneath the drift at both places being the upper limestone of the Traverse series. To the north of Petrolia the black Antrim shales again appear overlying the Traverse, at Wyoming, where they have a thickness of four feet and at Kingston's Mills, where they are fifty feet thick."

Petrolia.—A well sunk near the Imperial refinery at Petrolia and known as the "Test Well" as published by Mr. Brummell (Mr. E. Rawlings, driller) shows the following record:[9]

Test Well, Petrolia.—Elevation 667 feet A. T.

		Thickness.	Depth.	El. A. T.
Surface		104	104	563
Traverse	1. Limestone (upper)	40	144	523
	2. Shale	130	274	393
	3. Limestone (middle)	15	289	378
	4. Shale	43	332	335
Dundee	5. Limestone (lower)	68	400	267
	6. Limestone, soft	40	440	227
	7. Limestone, gray	160	600	67
Monroe	8. Limestone, hard, white with hard streaks of sandstone from two to five feet in thickness.	500	1100	*433
	9. Gypsum	80	1180	*513
	10. Salt and shale	105	1285	*618
	11. Gypsum	80	1365	*698
	12. Salt and shale	140	1505	*838

* Below sea level.

No. 5 is regarded by the Canadian geologists as constituting the base of the Traverse (Hamilton) series and 6 and 7 the Corniferous.

As the upper portion of these limestones are known only as they appear in well sections in Eastern Michigan and Western Canada it is evident that the attempt to draw a dividing line between the two divisions within the limits of a limestone formation, as represented by 5, 6 and 7, meets with insurmountable difficulties. The Michigan geologists have, therefore, very properly abandoned the attempt at exact correlation of these limestones with the Corniferous and have given to them the local name of Dundee which is defined to include all limestone beds extending down from the shales represented in No. 4, the "lower soapstone" to the dolomite or gypsiferous shales of the next or Monroe formation. The division between Dundee and the overlying Hamilton beds, which are likewise given a local name—the Traverse, is one of the sharpest lines we have and can be easily recognized in well borings. The oil is found at a depth of from 45 to 135 feet below the top of No. 5, which here has an elevation of 335 feet A. T.

Sarnia.—The productive oil territory extends northwest from Petrolia into the southeastern corner of Sarnia township where a number of wells have been sunk, the records of which, however, are not available.

[9] Compare record of Vol. V, part II, p. 46, showing Dundee at 345 to 375 feet.

At Sarnia, which lies in line with the extension of the longer diameter of the Petrolia field, several wells have been sunk in which gas in small quantities was obtained but no oil. Following is a record of Dickens well located in the southern part of the town near the corner of Rose and Tecumseh streets.[10]

Dickens Well, Sarnia.—Elevation about 590 A. T.

		Thickness.	Depth.	El. A. T.
Glacial	1. Surface deposit. Sand and clay 130. Hard pan 55. Gravel 15	200	200	390
Traverse	2. Limestone	90	290	300
	3. Shale	100	390	200
	4. Limestone	5	395	195
	5. Shale	68	463	127
Dundee	6. Limestone	77	540	50

This well is remarkable in showing the absence of the Antrim shales which at Port Huron, just across the river, are 82 feet thick in Wells bore hole (No. 12 in Vol. V of the Michigan Reports) and thicken rapidly westward to 183 feet at the Junction well.

Evidently the Dickens well marks the location of an extensive pre-glacial channel possibly representing the ancient Huronian river. The top of the Dundee limestone has here an elevation of 127 feet thus showing a westward pitch of the fold of 208 feet between this point and Petrolia.

Another well at King's gristmill, drilled in 1875 by M. E. Rawlings, gave the following record:

King's Gristmill well, Sarnia.—Elevation 589 A. T.

		Thickness.	Depth.	El. A. T.
Glacial	1. Surface deposit. Sand 9. Blue clay 109. Hard pan 2	120	120	469
Antrim	2. Shale, black	36	156	433
Traverse	3. Limestone	30	186	403
	4. Shale	263	449	140
	5. Limestone	5	454	135
	6. Shale	40	494	95
Dundee	7. Limestone	60	554	35
	8. Limestone, grey	100	654	*65
Monroe	9. Limestone, hard	546	1200	*611
	10. Limestone, hard and flinty	200	1400	*811
	11. Limestone with gypsum	105	1505	*916

* Below sea level.

[10] As given by Mr. Brummell (H. Mitchell, driller.)

Oil was not observed, but gas in small quantities was found at 400 feet and cased off.

This well is located about one and one-half or two miles north of the Dickens well and shows the presence of 36 feet of Antrim shales. The surface of the Dundee has an elevation of 95 feet or 32 feet lower than in the other well.

Courtwright.—A well at Courtwright, about 10 miles south of Sarnia, gave the following record as furnished by Mr. E. Rawlings, driller, and published by Mr. Brummell:

Courtwright well.—Elevation above tide 588 feet.

		Thickness.	Depth.	El. A. T.
Glacial	1. Surface sand and clay	132	132	456
	2. Hard pan	28	160	428
Antrim	3. Shale, black	32	192	396
Traverse	4. Limestone	40	232	356
	5. Shale and Limestone	310	542	46
Dundee	6. Limestone, white	50	592	*4
	7. Limestone, grey	100	692	*104
Monroe	8. Limestone, hard, white	370	1062	*474
	9. Sandstone†	32	1094	*506
	10. Limestone	400	1494	*906
	11. Limestone and gypsum	136	1630	*1042
	12. Salt	22	1652	*1064
	13. Gypsum	13	1665	*1077

* Below sea level.
† Probably dolomite (B). Sylvania (L).

In this well the top of the Dundee is found at 46 A. T. or 81 feet below its position at the Dickens well. It is evident that the fold passes through the south part of Sarnia, its summit being at or a little south of the corner of Rose and Tecumseh streets.

THE PORT HURON FIELD.

The only wells that have yielded oil in the Port Huron area are located on what is known as the Goodrich property in the western part of the city. They belong to the Michigan Development Company, of which Mr. G. B. Stock is the manager. Sixteen wells have been sunk, the larger part of which are pumped, yielding altogether about forty barrels a week. Those interested in the question are firm in the conviction that a larger pool exists somewhere in this region and are persistent in their attempts to locate it.

The Bailey and Stock wells are located near together and correspond closely in their records. The following, furnished by Mr. G. B. Stock, is a typical record of the wells in the Goodrich field:

The Stock wells.—Port Huron.

Location, S. ½, N. W. ¼, Sec. 9, T. 6 N., R. 17. Elevation 605 A. T.

			Thickness.	Depth.	El. A. T.
Glacial	1.	Blue clay	100	100	505
Antrim	2.	Black shale	87	187	418
Traverse	3.	Limestone (top)	43	230	375
	4.	Soapstone, soft	70	300	305
	5.	Limestone (middle)	15	315	290
	6.	Slate or shale, dark	85	400	205
	7.	Soapstone	120	520	185
Dundee	8.	Limestone, sandy	47	567	38
	9.	Limestone	33	600	05

The limestone No. 8 is the oil bearing stratum. The surface of the Dundee here has an elevation of 85 feet A. T. From this point the beds slope toward the northeast and to the west and south. Toward the south and west the slope is apparently pronounced, as shown by the following wells which are evidently located on the southwestern limb of the anticline.

Bailey well No. 1.—Port Huron.

Location 500 N., 1000 W., Sec. 9, T. 6 N., R. 17. About ½ mile southwest of the Stock wells. Elevation about 605 A. T.

(Plate 48, Vol. 5, Mich. Geol. Survey.)

			Thickness.	Depth.	El. A. T.
Glacial	1.	Surface	100	100	505
Antrim	2.	Black shale	100	200	405
Traverse	3.	Streak hard argillaceous limestone with Fes...	2	202	403
	4.	Soapstone (argillaceous marl)	15	217	388
	5.	Limestone (top) blow of odorless gas at 280	80	297	308
	6.	Soapstone (argillaceous marl)	147	444	161
	7.	Limestone (middle)	9	453	152
	8.	Soapstone with streaks of limestone at 518 and 525	90	543	62
Dundee	9.	Limestone (lower)	125	668	*63

* Below sea level.

Grand Trunk Junction well.—Port Huron.

Location at Grand Trunk Junction, near the N. E. corner, Sec. 18, T. 6 N., R. 17 E. Elevation 618 feet A. T.

(Plate 54, Vol. 5, Mich. Geol. Survey.)

			Thickness.	Depth.	El. A. T.
Glacial	1.	Surface	124	124	494
Antrim	2.	Black shale, small amount of gas at 300	183	307	311
Traverse	3.	Limestone (top)	128	435	183
	4.	Soapstone	77	512	106
	5.	Limestone (middle)	8	520	98
	6.	Soapstone	105	625	*7
Dundee	7.	Limestone (lower)	147	772	*154

* Below sea level.

Black water was encountered at 680-685 and salt water at bottom. A show of oil appeared at 710.

Marysville well.

Location four miles south of Port Huron, on the Bunch farm, put down by Church & Co. Elevation about 600 feet A. T.

(Plate 40, Vol. 5, Mich. Geol. Survey.)

			Thickness.	Depth.	El. A. T.
Glacial	1.	Clay	107	107	493
	2.	Gravel (dry)	3	110	490
Antrim	3.	Dark blue shale, streaks of black	188	298	302
Traverse	4.	Gray limestone	97	398	205
	5.	Argillaceous marl thinly laminated and fissile	193	588	12
Dundee	6.	Sandy limestone, porous, indications of gas	37	625	*25
	7.	Limestone, grey	390	1015	*415
Monroe	8.	Limestone, sandy	80	1095	*495
	9.	Limestone, dark grey, hard in places	55	1150	*550

* Below sea level.

Salt water was encountered in No. 7 at 745 and mineral water at 817, 970 and 985. The upper part of these limestones probably belongs to the Dundee.

About ¾ of a mile southeast of Wadham's station, on the farm of Mr. Fair near the railroad track, a well was sunk by Mr. G. B. Stock who furnished the following record:

The Fair well.—Wadham's Station.

Location S. E. ¼, Sec. 2, T. 6 N., R. 16 E. Elevation about 655 feet A. T.

		Thickness.	Depth.	El. A. T.
Glacial	1. Surface gravel	4	4	651
	2. Blue clay	110	114	541
Antrim	3. Black shale	122	236	419
Traverse	4. Limestone (top)	230	466	189
	5. Soapstone	105	271	84
	6. Limestone (middle)	45	616	39
	7. Soapstone	95	711	*56
Dundee	8. Limestone (lower)	122	833	*178

* Below sea level.

No gas or oil was found in this well.

A well sunk by Mr. G. B. Stock on the farm of F. A. Beard, ten miles northwest of Port Huron, gave a heavy flow of mineral water at 140 feet, another of brine at 587 feet with a slight show of oil at 813. The record of this well, which is located in the valley of Black river at the mouth of Mill creek, was furnished by Mr. Stock.

Beard's well.—Abbottsford.

Location near S. E. Cor. Sec. 8, T. 7 N., R. 16 E. Elevation about 655 A. T.

		Thickness.	Depth.	El. A. T.
Glacial	1. Marly clay	30	30	625
	2. Tough blue clay	86	116	539
	3. Wash gravel	22	138	517
Antrim	4. Black shale	100	238	417
Traverse	5. Limestone (top)	217	455	200
	6. Soapstone	122	577	78
	7. Limestone (middle)	4	581	74
	8. Soapstone	156	737	*82
Dundee	9. Limestone (lower)	96	833	*178

* Below sea level.

A heavy flow of water of excellent quality which came out with considerable force when first struck was found in gravel (No. 3) at the base of the surface formation. This well was still flowing in considerable volume at the time of our visit. Instead of coming up the pipe the water had forced its way up outside and had made a considerable opening all around the pipe. Bubbles of gas were constantly given off by the water as it boiled up from below. The "top limestone" shows unusual thickness in this well and in the Shaw well hereafter described.

The westward descent of the Dundee is well shown here, the surface lying at 82 feet below the sea level while at the Stock wells in Port Huron it is 85 above, a difference of 167 feet. At the Fair well there is a descent of 141 feet, at the Junction well 92 feet, while at Marysville it

is 73 feet. At the Bailey well (No. 1) the surface of the Dundee is 23 feet lower than at the location of the Stock wells though the distance between them cannot exceed one-half mile.

Westward from Beard's well the inclination of the beds evidently continues as shown by the well put down at Valley Centre, in Sanilac county, which stopped in "top limestone" at a depth of 876 feet. This well was put down by a local stock company of which David Murray is manager. The record was furnished by Mr. Lewis Hydorn who assisted in the drilling:

Valley Centre well.

Location S. E. ¼, N. E. ¼, Sec. 27, T. 9 N., R. 13 E. Elevation 805 A. T.

		Thickness.	Depth.	El. A. T.
Glacial	1. Red sand and loam	5	5	800
	2. Quicksand	90	95	710
	3. Clay	22	117	688
	4. Sand and gravel with plenty of pure water	32	149	656
Marshall	5. Sandstone	5	154	651
	6. "Conglomerate"	20	174	631
	7. Sandstone	30	204	601
Coldwater	8. Slate (blue shale)	10	214	591
	9. Soapstone	175	389	416
	10. Slate	150	539	266
Berea	11. Limestone	10	549	256
	12. Sandstone	20	569	236
Antrim	13. Shale changing to soapstone below	272	841	*36
Traverse	14. Limestone	35	876	*71

* Below sea level.

The formations 5, 6, 7 here indicated as belonging to the Marshall group may be the equivalent of the Richmondville sandstone within the Coldwater series. Assuming a thickness of 400 feet for the Traverse here, it is evident the Dundee would be found at a depth of about 1241 feet or 436 feet below sea level. From this it appears that the descent of the Dundee limestone between Port Huron and Beard's is about 16½ feet per mile, while between Port Huron and Valley Centre the top of the Traverse shows a westward descent of 15 feet per mile, a reasonably close correspondence.

Turning now to the wells northeast of the Stock area we find a descent of the beds in that direction, though not so marked, indicating that the few wells put down here are near the broad summit of the anticline.

A well was put down by F. L. Wells some years ago, the record of which was published in Volume V of the Michigan Geological survey. This well is located about a mile east (and a little north) of the Stock wells on the bank of Black river a short distance above Seventh street bridge.

Well's Bore Hole.—Port Huron.

Location, bank of Black river opposite Kern's Brewery.* Elevation 585 A. T.

(No. 12, Plate 57, Vol. V.)

		Thickness.	Depth.	El. A. T.
Glacial	1. Surface, mostly clay	102	102	483
Antrim	2. Black slate and shale	83	185	400
Traverse	3. Limestone (top)	105	290	295
	4. Soapstone with seams of limestones	225	515	70
	5. Limestone (middle)	.....	.....	.....
	6. Soapstone	.....	.....	.....
Dundee	7. Limestone (lower) cherty at top with show of oil and gas	133	648	*63
Monroe	8. Dolomitic limestone with indications of salt and gypsum	68	716	*131
	9. Marl and marly limestone	54	770	*185
	10. Hard dolomitic limestone	75	845	*260
	11. Bluish black marl with gypsum	58	903	*318
	12. Hard dolomitic limestone with show of brine and oil	42	945	*360
	13. Argillaceous marl with streaks of dolomitic limestone and gypsum	205	1150	*565
	14. Hard gray calcareous sandstone. (Oriskany?)	95	1245	*660
	15. Bluish black argillaceous marl	10	1255	*670
	16. Dolomite and gypsum	300	1555	*970
	17. Alternating beds of salt limestone and shale	130	1685	*1100

*Below sea level.

At the top of the Traverse was found a thin bed of shale overlain by a streak of hard argillaceous limestone containing FeS_2.

At the time of our visit a well had just been completed on the Sweitzer property about a mile and a half north of the Stock wells, by L. W. Holt for a stock company. The record of this well as furnished by Mr. Holt follows:

Sweitzer well.—Port Huron.

Location S. W. ¼, Sec. 33, T. 7 N., R. 17 E. Altitude about 610 A. T.

		Thickness.	Depth.	El. A. T.
Glacial	1. Soil and sand	5	5	605
	2. Clay	100	105	505
	3. Hard pan and marl	15	120	490
Antrim	4. Black shale	100	220	390
Traverse	5. Limestone, white with thin strata of soapstone	60	280	330
	6. Soapstone	278	558	52
Dundee	7. Limestone (lower)	62	620	*20

* Below sea level.

There was a show of oil at 558. The well was shot at 568 and a small amount of oil obtained. Another well (No. 2) was in progress a short distance from No. 1. This well, as also the Wells boring, reaches the Dundee at a slightly lower level than the Stock wells but all are evidently not far from the crest line of the fold.

* Where wells have been put down for water.

A little more than four miles north of Sweitzer's on the farm of Mr. Shaw, a boring was made by G. B. Stock who furnished the following record:

Shaw well.—Fort Gratiot township.

Location S. E. ¼, Sec. 8, T. 7 N., R. 17 E. Altitude about 600 A. T.

		Thickness.	Depth.	El. A. T.
Glacial	1. Sand and gravel	5	5	595
	2. Purple clay or mud	30	35	565
	3. Gravel	3	38	562
	4. Blue clay	79	117	483
Antrim	5. Black shale	45	162	438
Traverse	6. Limestone	203	365	235
	7. Soapstone	95	460	140
	8. Limestone (middle)	15	475	125
	9. Soapstone	65	540	90
Dundee	10. Limestone (lower)	115	655	*55

* Below sea level.

This record shows an unusual thickness of the "upper limestone" (No. 6) while the soapstone is proportionately decreased in thickness. A showing of oil was claimed to appear here at 557 but no effort was made to develop it further and the well was abandoned.

Northward from this point the beds descend and other rocks appear overlying the black shale. At Papst's well three miles south of Lexington there are 252 feet of shales including a thin bed of limestone above the black Antrim shale. The record of this well furnished by the driller is of doubtful utility for purposes of correlation, and is not given here.

The accompanying map (not printed, open to the inspection of those interested. L.) shows the configuration of the surface of the Dundee limestone as nearly as it can be determined from the data available. From this it will be seen that the crest of the fold is marked by a line passing northwestward through the southern and western portions of Port Huron then veering northward. The fold plunges steadily in the direction of its course while to the westward it is bordered by a synclinal trough which likewise descends to the north and west. The wells at Mt. Clemens and New Baltimore[11] show another fold coming in from the southeast.

While the information derived from additional well borings will undoubtedly call for modifications of this map in details it is believed that in its essential features the surface of the Dundee limestone will be found as here represented. If correctly represented it is evident that oil must be sought along the crest of the Port Huron fold.

As the fold plunges to the northwest the tendency of the oil would be to seek the highest points and hence would follow the rock toward the southeast unless intercepted by transverse depressions. Thus far no indications of "pools" have been found.

[11] See pp. 221 to 223.

The following paper on the erosion of the shore just north of Port Huron which was taken up by Dr. Gordon incidental to his work on the Port Huron oil field, has interest in a number of ways. In the first place the actual commercial loss of land is not inconsiderable. Much of the fine clay, however, is doubtless swept down the Saint Clair river and reappears in the gain of the Saint Clair flats. Again we have interesting data to be applied elsewhere upon the possibilities of erosion of the till. While the effect of the rise and fall of the lake level is very marked in hastening or retarding erosion, in the period used the lake level was about the same at the beginning and at the ending. It will be noticed that the rate of erosion found is in harmony with that found in the Huron county, so that the estimates as to the length of time that erosion has been taking place at or near the present level will not need to be materially modified. It is, however, quite likely that when the bluffs were thickly wooded the trees, as they were undermined and slid down, would greatly protect the bank from erosion. This is indicated by the greater erosion during the later period.

WAVE CUTTING ON WEST SHORE OF LAKE HURON, SANILAC COUNTY, MICHIGAN.

BY C. H. GORDON.

At various places along the shore in Sanilac and Huron counties the encroachment of the lake upon the land is proceeding at an appreciable rate. In Sanilac county there are a number of reaches where the water breaks fairly against a bank twenty to twenty-five feet high, composed of boulder clay overlain occasionally by the stratified sand and gravel of abandoned beaches. As some of these localities indicate that shore destruction has gone on practically unhindered by artificial means since the settlement of the region it was suggested by State Geologist, A. C. Lane, that a study of a typical locality might afford data from which a quantitative estimate of the encroachment of the lake in recent times could be derived.

LOCALITY.

Accordingly during the summer of 1901 a site was selected 3½ miles south of Lexington which seemed to offer especially favorable opportunities for this investigation. The shore here forms the eastern boundary of the Haywood estate (Figures 5 and 7) comprising the S. ½ of the S. ½ of section 18 and the N. ½ of the N. ½ of section 19, T. 10 N., R. 17 E., where it was evident no effort had been made by cribbing to prevent the cutting away of the land. At this point the direction of the shore line is S. 17° E. with a slight bend to the west. The vertical escarpment is about twenty feet high composed wholly of glacial till. At the southeastern corner (G on Fig. 5) sand and gravel appear over the clay thickening toward the south as the shore line cuts diagonally across the old beach to which it belongs. Behind this beach line a small ravine or dry run comes in from the south while another intersects the bluff 40 rods north of the south boundary line. The land has been cleared and under cultivation for many years.

A distinct impression of recency in lake encroachment is gained by observing in places plow furrows cutting straight out to and across the edge of the bluff. At one point three distinct stages of cultivation were noted. First the oldest plow furrows at right angles to the bank extending clear out to the edge, the corresponding north-south furrow having been removed by the waves. Second, outermost furrows parallel with the cliff and within six feet of the edge, a position it would be impossible to reach by the plow at the present time. Third and last, with the outermost furrow about ten feet from the edge. These stages are all clearly defined and indicate a distinct encroachment of the lake between each

period of cultivation. Opposite the north boundary of this estate at E, Mr. Papst, who owns the property on the north, has placed a crib of logs which has checked shore wash here and inaugurated a stage of land building.

The Shore Line.—The shore line at this point belongs to the type designated by Lane in the Huron county report[1] as the cliff and shingle type. In this case the cliff, with vertical inclination about 20 feet high, is composed of boulder clay. Farther south the shore line intersects an old beach, the Algonquin, the top of which is 20 to 25 feet above the present lake level. This is one of the most pronounced beaches of the series described in the Huron and Sanilac county reports. South from this point it appears as a well developed ridge or belt of sand and gravel. Northward in Sanilac county it appears only in isolated stretches having for the most part been cut away by the encroachment of the lake. Plate XV represents the beach cliff at a point about one-fourth mile south of the Haywood estate. At this point the stratified beach deposits rest upon the boulder clay which to the north constitute the whole cliff section. The plane of contact between the beach deposits and the underlying clay is marked by pieces of coniferous wood in the form of logs and stumps of various sizes. One of these is seen projecting from the bank to the right of the hat in the left foreground of the picture. About a hundred yards south of the place where this view was obtained the surface of the clay descends to near lake level and logs and stumps of considerable size, evidently washed out of the bank, strew the shore.

Stratification of Clay.—Owing to the recent removal of material the face of the cliff is remarkably fresh and offers excellent opportunity to study the character of the deposit. Exclusive of the 18 inch soil horizon on top, there are three well marked divisions in the clay all characterized by more or less clearly marked stratification planes. Following is the section taken here:

		Feet.	In.
1.	Soil—top loam	1	6
2.	Light colored, or drab sandy clay. Rather obscurely but evenly and regularly stratified: pebbles mostly of small size	9	0
	(a) Between this and the underlying clay is a brownish band, in places consisting of yellowish sand, filling irregular depressions in the lower clay. This apparently represents a soil horizon. Thickness	6 in. to 1 ft.	
3.	Blue clay, darker and more compact than No. 2. The stratification is well marked and fairly regular. It is well shown in Plate XII. The contact between this and the overlying division is marked by a more or less clearly defined unconformity. The clay is distinctly jointed and contains more numerous and larger pebbles, many of which are distinctly striated. Thickness	7	0
4.	Below No. 3 there is exposed four feet of darker blue and still more compact clay, stratified, the layers being decidedly contorted. It is separated from No. 3 by a well marked seam or crack but shows no appearance of a soil horizon. The surface of this lower clay bed is irregular but the layers of		

[1] Lane, A. C.—Geological Report on Huron County, Michigan.—Geological Survey of Michigan, Vol. VII, p. 40.

	Feet.	In.
the overlying bed fit conformably into the depressions. The boulders in this bed are prevailingly of dark crystalline rock and are, for the most part, subangular in outline and often planed and striated. Thickness exposed.....	4	0

The three divisions, 2, 3 and 4, are clearly marked and for the most part can be readily recognized in Plates XI to XIII. They undoubtedly mark three distinct stages in the advance of the ice sheet. The compact contorted condition of the lowermost division shows the effect of the overriding of the ice in its next forward movement. In No. 3 the effect is much less, indicating that the movement was much less pronounced.

FIRST SURVEY.

The land survey notes on file at the county court house, Sanilac Center, show that the original survey was made by Lewis Lyon, deputy surveyor in 1823. Following is a transcript of the field notes of the meander of the east boundary of sections 18 and 19, T. 9 N., R. 17 E., beginning at point where north line of section 18 intersects the lake:

Direction.	Distance chains.	Remarks.
S 16 E	41.00	At 39.50 a stream 25 links wide enters from N. W.
S 10 W	3.50	
S 17 E	11.00	
S 14 E	12.50	
S 33 E	3.00	
S 22 E	5.50	
S 18 E	4.50	
S 2 E	2.90	To corner of fractions 18 and 19.
S 27 E	3.50	
S 13 E	12.00	
S 26 E	15.00	
S 40 E	5.00	
S 15 E	12.00	
S 30 E	8.00	
S 13 E	9.00	
S 12½ E	20.97	To fract. corner of 19 and 30.

Starting from the northwest corner of section 18 the distance to the lake, according to the Lyon's survey, was 24.50 chains. From the southwest corner of section 18 on line between 18 and 19, the distance to the lake was, according to same survey, 46 chains, and along the south line of section 19 it was 73.70. The meander of the shore according to these measurements is shown on the accompanying map.

RESURVEY.

To obtain exact data for an estimate of rate of shore cutting a survey was made by us with the assistance of county surveyor, Thomas Nicol, with the following results:

Starting from the southwest corner of section 18 the distance to the

lake (A B) was found to be 38.60 chains instead of 46 as shown by the survey of 1823. In Lyon's field notes, a hemlock 26 inches through occurred at 15.95 chains from corner. The stump of this tree was found by us at 15.90.

One-fourth mile north along quarter section line bounding the Haywood property on the north (D E) the distance to the lake measures 33.71 chains while that on the south (F G) in like manner measures 46.76 chains.

Starting from the point where the north quarter section line meets the lake the meander of the shore line for the half mile bounding the Haywood farm is as follows:

Direction.	Distance chains.	Remarks.
S 2 W	2.73	
S 12 E	6.85	At 1.76 a small run.
S 17 E	2.28	
S 22 E	3.87	
S 17 E	16.62	To elm tree. A small ravine enters from west at 7.
S 24 E	9.85	Stake set. Bluff 30 links east. Ravine 9 links west. Small stream enters lake from south at 7.85.

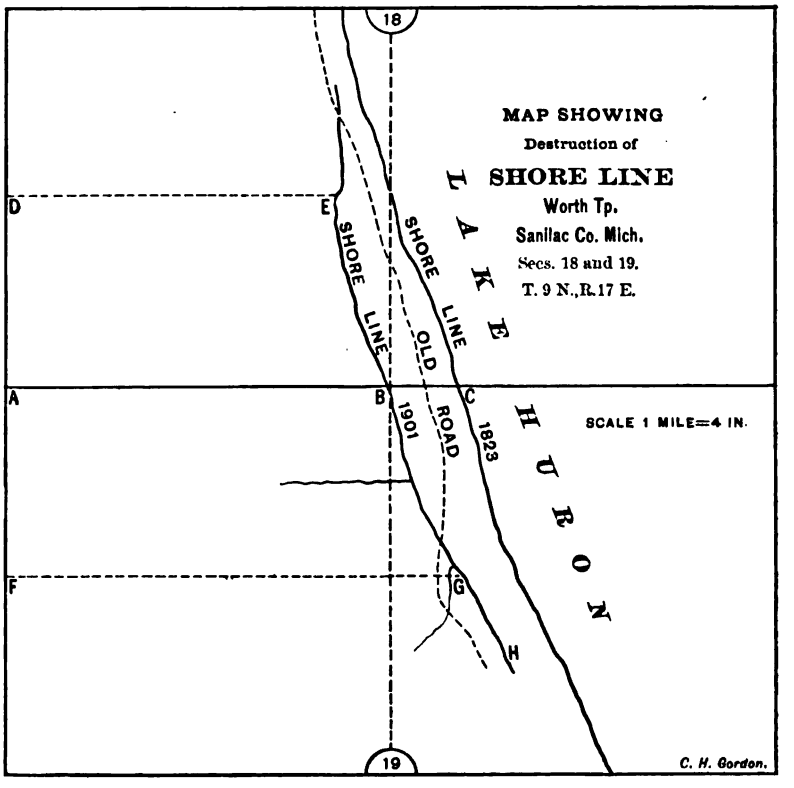


Fig. 5. Sketch map showing the advance of lake Huron, in Worth township, Sanilac county, Mich., at an average rate of 5.7 feet per annum.

The estate of Clark Haywood of Cleveland owns the south part of the south part of Sec. 18 and the north part of the north part of Sec. 19.

RATE OF WASTE.

The shore according to this 1901 survey is shown on the map, Fig. 5, in connection with that of 1823. According to the original survey the Haywood estate contained 184.90 acres and this is the size of the farm as indicated on the county maps. The new survey shows an area of 157.65 acres. It appears therefore that 27.25 acres of land have been removed by the lake in the 79 years intervening since the first survey, or an average of .345 acres per annum. The total average recession of the shore line within the area under consideration is 6.81 chains or 449.46 feet an average recession of 5.7 feet per annum.[2]

Old Government Road.—According to Mr. R. Papst, the old government road from Port Huron to Port Austin followed the lake shore here at a distance of several rods. Well marked traces of this old road can be found on Mr. Papst's farm. This road can be traced to where it crosses the edge of the bank 40 rods north of the north boundary of the Haywood estate and again on the south where it appears following the strand line. Near this point it is said that an orchard existed on the side toward the lake but its site has now entirely disappeared. On the Haywood estate the road lay entirely outside the present shore line as indicated on the accompanying chart.

Material removed.—The cubical contents of the portion of land removed equals the volume of a block 2,640 feet by 449.46 feet by 20 feet, in which the average height of the missing portion is taken to be the same as that of the present bank, a conclusion warranted by the appearance of the ground slopes. This yields 878,944 cubic yards of earth, an amount sufficient to cover an area of 545 acres to a depth of one foot, or an average of 6.9 acres per annum. According to the United States survey charts the area of Lake Huron is 22,322 square miles and the average depth of water about 200 feet. The length of coast line is about 500 miles. Assuming a uniform rate of cutting and filling, corresponding to that found above, it would take about 4,000 years to cover the bottom of the lake to an average depth of one foot or about 800,000 years to complete the filling of the lake. But the rate of cutting here is probably a maximum or at least more than the average and hence, on this assumption, a still longer time of stable conditions would be necessary to bring about the complete filling of the lake. The changes going on in the lake region make it evident that long before that stage is reached the lake will have lost its waters possibly in part through the reopening of drainage down the Illinois valley.

OTHER HISTORICAL DATA.

Old residents at Lexington remember when wave cutting was proceeding along the village shore at a rate approximating nearly a rod per year. The greatest cutting took place during the years of high water, in 1870 and '71 and in 1885 and '86. In the former years the lake was

[2] An estimate by planimeter and scale from the field sheets of the Lake Survey (photographed in Fig. 6) shows that at the time of that survey, August and September, 1859, the south line of Sec. 18 was about 44 chains long, the old road referred to below being shown as continuous on the map. The area of the Haywood estate was then about 176 acres. This implies a waste of 9 acres or 4.18 feet per annum in the 36 years from 1823 to 1859, and about 18 acres or 7.2 feet per annum in the 47 years since from 1859 to 1902, the greater rate of erosion in the later interval, being I suspect due to the removal of the forest protection-L.

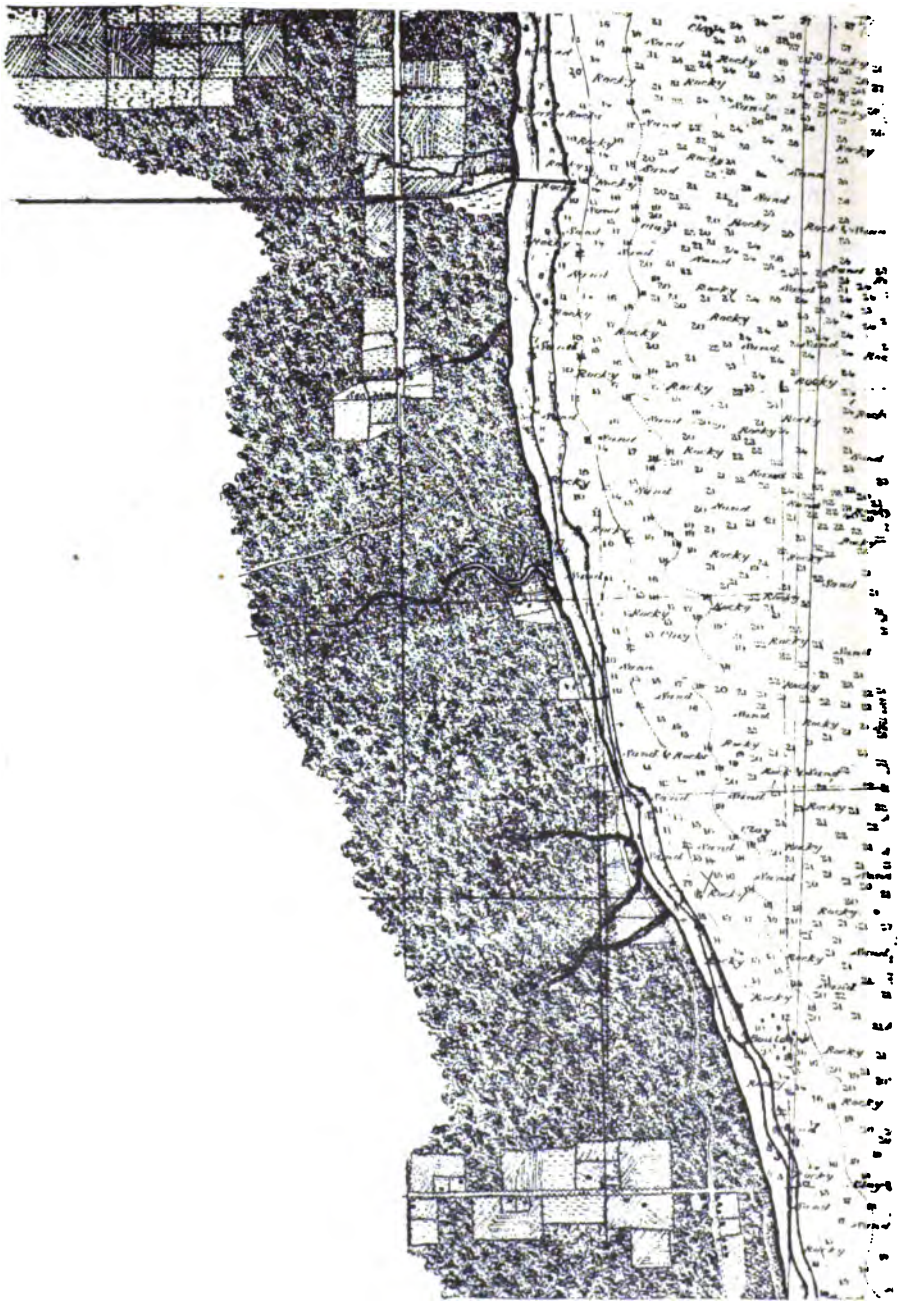


Fig. 6. Photograph from the original sheet (from which the map of Fig. 7 was made), showing the shore in Sections 18 and 19 at the date 1858.

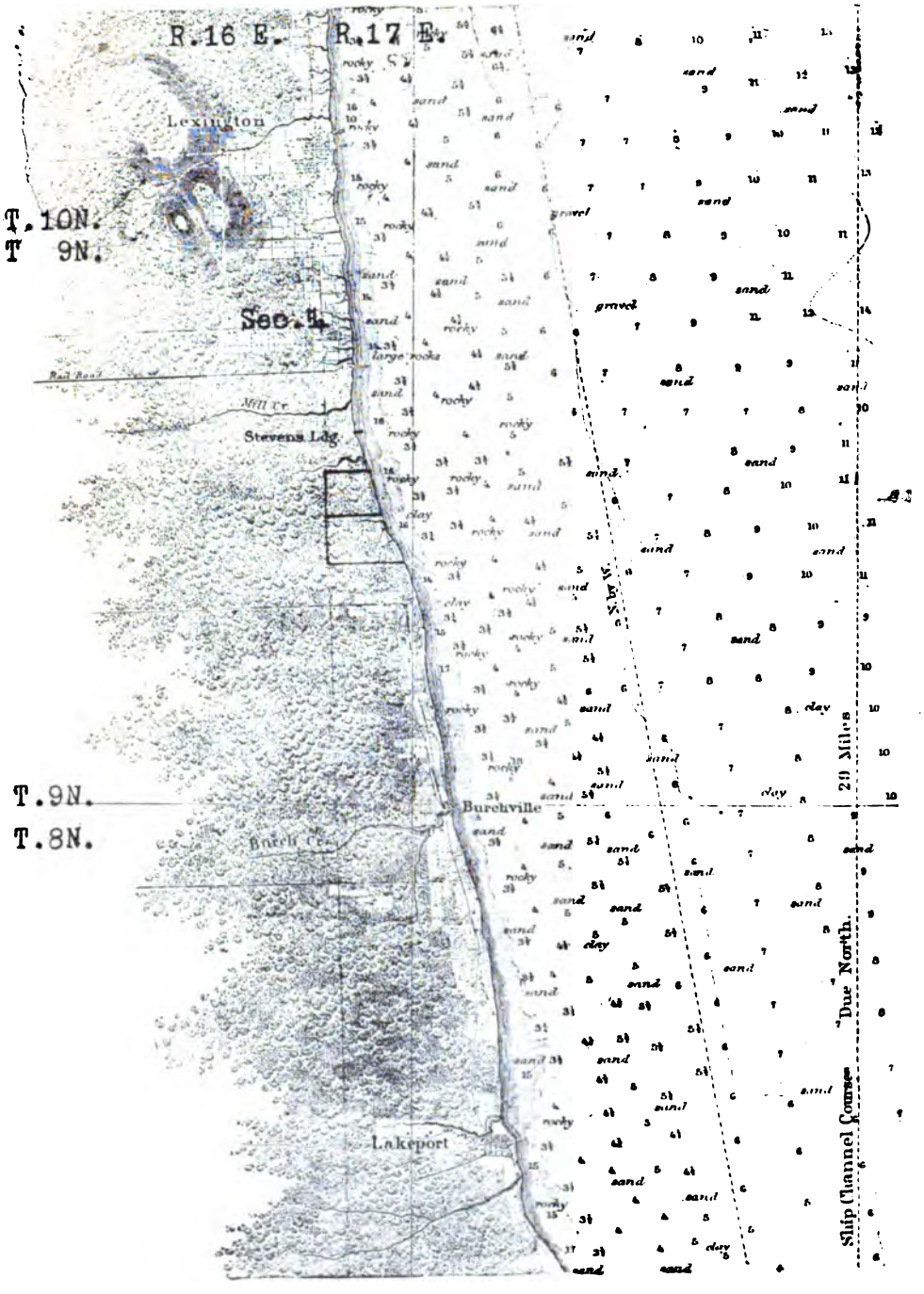


Fig. 7. Extracts from the Lake Survey map of the south end of Lake Huron, showing the location of the maps, Figures 5 and 6.

undercutting the bank south of the mill at the foot of Huron avenue. The most extensive cutting took place opposite the Lucia property just outside the village limits on the south. It is related that during[3] the years of high water, twenty years ago, a coal barge was driven ashore opposite the latter place in such fashion that the nose of the vessel was squarely against the bank with bowsprit extending out over the land. The position where the boat lay is now dry land. Of late years accretion has been going on at a rate of 10 to 30 feet per year. The amount thus gained at the foot of Huron avenue is 244 feet.

Previous to 30 years ago cutting was quite general all along the shore but since that date it has been to a considerable degree checked wherever cribs have been put in.[4]

[3] We are indebted to Judge Beach and R. Papst for the data referring to conditions in former years.
[4] The changes just north of Port Huron have been subject matter for a complicated law suit, the decision upon which we do not yet know.

ILLUSTRATIONS.

PLATE XI.

Clay Cliff and Shingle Shore line.
View looking south from north line of Haywood estate. The threefold character of the section can be recognized. The soil horizon separating the upper and middle divisions can be readily distinguished.

PLATE XII.

View looking north in same locality. The stratification planes in the middle division are plainly shown.

PLATE XIII.

A Cave In. The tumbled masses in the foreground are blocks of clay fallen from the cliff in the time intervening between two visits to the locality. With the coming of a storm the waves will dash upon the shore and soon reduce these masses to a pulverized condition, dropping the boulders and pebbles upon the beach and carrying the finer material away to settle in deep water beyond the action of the waves. Through undercutting by the lake the tree has been thrown from its perpendicular attitude but with noble persistence has sought to regain it.

PLATE XIV.

Where the Waves Work. A general view looking northward from the top of the cliff on the farm south of the Haywood estate, showing the nearly flat country behind the cliff.

PLATE XV.

Algonquin Beach and underlying clays. At the contact of the two near the hat at the left of the center of the picture, a small tree trunk may be seen projecting from the bank.

VIEW LOOKING SOUTH FROM NORTH LINE OF HAYWOOD ESTATE.

VIEW NORTH FROM NORTH LINE OF HAYWOOD ESTATE, SHOWING BEDDING LINES OF MIDDLE DIVISION.

CAVED MASSES OF CLAY, SANILAC COUNTY BLUFFS, AWAITING WAVE DESINTEGRATION.

GENERAL VIEW, CLIFFS AND FLAT COUNTRY, LOOKING NORTH OVER HAYWOOD ESTATE.

ALGONQUIN BEACH AND UNDERLYING CLAYS EXPOSED IN BLUFFS.

INDEX.

INDEX.

N. B.—The names of shells of the marls on page 138, and of fossils between pages 161 and 210 are not indexed.

Page.

Abbottsford 278
Acervularia beds 202, 203
Agassiz, A. 245
Agricultural College 256
Agricultural resources 28
Air temperatures 245, 247, 251
Alabaster 16
Alcona county 9, 28, 31, 34, 35, 37
  agricultural resources of 28
  history of 36
  railroads in 37
Algonquin beach 53, 284, 291
Alpena 54, 77, 155, 163, 165-168, 184, 248
  limestone 180, 182, 210
  wells 67
  Portland cement 170
  Portland Cement Co., limestone from quarry of 181
Altitudes 6, 42, 43, 44
  See also elevations of wells from p. 267 on.
Alumina 15
Analyses 66
  Alpena limestone 181
  Arenac limestone 15
  Bayport quarry 153
  bed of Slate Creek, Huron Bay, T. M. Chatard 143
  bog lime (marl) 155
  brine, Muskegon 233
    Detroit 242
    Saginaw valley 242
  clay 26, 27
  Warner brickyard clay 195
  Dock street clay 192
  of dolomite 144, 147
    of Michigan dolomites 142
    of Randville dolomites 142
    of dolomites from Sunday Lake, W. T. Hildebrand 143
    of Khagashewung Pt. dolomites 207
    of ferrodolomite, Marquette district 143
    of Hudson group, Koenig 145
    of Traverse group 209
    of iron carbonates Sec. 13, T. 47 N., R. 46 W 143
      Palms Mine 143
  limestone 142
    from Alpena Portland Cement quarry 181
    of cement quarries 182
    of Collin's quarry 179
    of Niagara 146
    of Omer 14
    of Petoskey limestone 200

Page.

Analyses, limestone, from Mr. Griffin's quarry 182
near Roger's City 181
from Sibley quarry 150, 151
(Bell shale?) 181
of shale from Mr. Wiesey's well 188
of the Warner brickyard clay 195
of oil 229
water 24
See also brines.
Ann Arbor 215
Antrim (Genesee, St. Clair) shales 209, 210, 216, 225, 273
Archean 142, 143
Arenac County 9, 15, 17
Archean dolomite, analyses by Rominger 156
Arsenides 133
Artesian well temperatures 248
Asphalt 229
Au Gres river 16, 23, 24
Au Sable 22, 64, 69

Bailey well 276
Bangor 214
Basin-like arrangement of beds in L. P. 124
Bay City 224
Bay City well 250
Bay county 6, 253
Bay de Noc 228
Bay port limestone 152
Bay Shore Lime Company's quarry 206
Bayview well 197
Beach deposits 284
Beard's well 278
Bear Creek 201
Beet sugar 5, 123, 149
Bellevue quarry 152
Bell shales 175, 191, 197, 210
Berea grit 48, 68, 70, 71, 72, 74, 128, 224, 225, 226
Berrien county 252
Berrien Springs 213
Bigsby, J. J. 163
Bituminous shale 20
Blissfield 219
"Bog lime" (marl) 154
Bolton 182
Brady, W. E. 77
Brady, F. 179
Brickyard, Standish 26
Brine analyses 233, 236, 242
Britton 219
Bromine 135
Brownlee well 218
Bryozoa beds 201

Calciferous 227
Callendar, Hugh L. 246
Canadian rocks 49
Canada, geological survey of 269
Case, Julian N. 144
Cass City 155
Cement 13, 135
Channel, ancient ice 100
Chara 98, 99
Charlevoix wells 197, 210

Page.
Chatham 144
Chazy 227
Cheboygan 230, 248, 249
Chlorastrolite 136
Church 253
Churchill well 68, 69, 169
Cincinnati anticlinal 272
Cincinnati group 145
Cincinnati, analysis by Rominger 156
Clay 25, 61, 62, 63
analyses of 26, 62
deposits 28
stratification of 284, 291
and shales 25
Coal 5, 6, 18, 64, 75, 137
measures 225
Coldwater 225, 233
shale series 66
Collin's quarry limestone 179
Columbiaville 108, 116
Combination 130
Competition 130
Consolidations 131, 136
Converter linings 135
Cooper, W. F. 257
Copper 131, 133
in Arenac county 12
Range Company 132
Correlation in industries 125
Coryell, Mr. 24

Davis, C. A. 137
Dean, J. G. 181
Deep River 20, 22
Detroit brine, analyses of 242
river 149, 241
Salt Company 218
Devonian 49, 236, 243
(Antrim) shales 66
See Antrim, Bell and Traverse.
Diamonds 136
Diatomaceous earth 107
Dickens' well 274
Diffusivity 247, 251
Divergence of plumb bobs 255
Dolomite 141, 219
analysis of. See Analyses.
of Monroe county 148
Dow, H. H. 148, 179
Dryer, C. R. 51
Dundee (Corniferous) limestone ..68, 70, 148, 151, 175, 191, 197, 216, 219, 220, 221, 222, 223, 226, 273.

East Saginaw first well 249
Eau Claire, Berrien county 252
Ecorse river 241
Educational interests 258
Engineering Society 259
Eocarboniferous 225
See also Coldwater.
Erosion 287
of shore 282
Escanaba, Delta county 228

Page.
Fairchild, H. L. ... 51
Favosites ... 178
Fletcher well ... 173
Flowing wells ... 20, 24, 25, 58, 59, 67, 68, 70, 72
Forsyth, R. J. ... 142
Fort Wayne outlet ... 51, 52
Fossils ... 13, 138, 161 to 210
Fox's quarry ... 180
Franking privilege ... 263

Gas ... 6, 73, 128, 236, 237, 275
Genesee county ... 117
Geology, economic ... 121
Geophysics ... 255
Geothermal gradient ... 244
Gilbert, G. K. ... 51
Glacial channel ... 100, 110, 113, 116
Gladstone ... 145
Gold ... 136
Gordon, C. H. ... 211, 267, 269
Grabau, A. W. ... 67, 70, 77, 152, 163, 179
Grand Ledge ... 252
Grand Rapids ... 153
Grayling ... 155, 231, 250
Greenbush ... 53
Gregory, W. M. ... 9
Griffin, M. J., quarry of ... 77, 153, 182
Grindstone ... 134
Grinold, E. R. ... 252
Gypsum ... 12, 15, 49, 152, 264, 273

Hahn, H. C. ... 242
Hamilton beds ... 273
Harrisville township ... 43
temperature and precipitation at ... 40
Haywood estate ... 283
High schools, teaching of geology, etc., in ... 258
Honey combed limestone ... 65
Horton, Robt. E. ... 260
Houghton, Douglas ... 37
Hubbard, Bela ... 51
Hubbard lake ... 45
Hubbard, Dr. L. L. ... 132
Hudson river group ... 145
Huronian ... 142

Ice age ... 5, 50
deposits of ... 45, 46, 47, 48, 49, 52, 54, 60, 104
in Lapeer county ... 112–116
See also the well records from p. 211 on.
Ice sheet, stages in ... 285
Illinois Steel Company ... 77
Imlay outlet ... 52
Iosco ... 9, 15
Iron ... 15, 128, 131
country ... 264
ore ... 129, 130

Jarman's quarry ... 204

Kedzie, F. S. ... 66
Keweenaw Point ... 249
Khagashewung Pt. ... 206, 211
Killmaster ... 34, 38, 65, 67

Page.
Lake Algonquin 51, 53, 55
bottom, tilting of 123
Huron 54
level fluctuations of 55, 105, 123
Maumee 51, 52
Ogemaw 22
Lakes 45
Lake Saginaw 48, 51
Superior Mining Institute 257
sandstone 50
Warren 48, 55
Whittlesey 52, 55
Lambton county, oil of 272
Land Commissioner 259
Lane, A. C. 57, 164
Lapeer county 108
geology of 111
Lansing 211
Lead in Alcona 11, 76
Leipsic beach 115
Lenawee 253
Lexington 287
Leverett, Frank 31, 51, 72, 108, 260, 261
Limestone 11, 14, 31, 35, 179
formation 64
honey-combed 65, 73
for macadam, cement, converter lining 135
from Alpena Portland Cement Co.'s quarry 181
near Roger's City 181
Traverse 184
uses of 141
Trenton 229
See also Analyses.
Little Traverse Bay region 197
Livingston, Dr. Burton E. 77, 79
Location, economic importance of 122
Lockport 228, 231
Lorraine (Hudson R.) shales 228, 231
Lower Grand Rapids 225, 232
Helderberg 147
Marshall 225, 233

Macadam 135
Magnesia 15
Magnesian beds 206
Mammoth 252, 253
Manfield's creek 26
Manistee 212, 235
Marble 144
Marl 60, 61, 117, 154
Marquette brownstone 134
Marshall sandstone 64, 234
Marysville well 277
Mason, J. J. 108
Mastodon 252, 253
McLeod, C. H. 246
McMillan, James 261
McLouth, Prof. C. D. 104
McNair, F. W. 255
Medina 223, 231
Melbourne 224
Mendon 214
Mesabi Range 128, 129

Page.
Mesodevonian (Traverse group) 226, 232
Meteorites 243
Michigan Academy of Science 259
alkali 136
analyses by Rominger 157
Oil Company 234
series 152
Midland 141
Milan 219
Mine maps, filing of 263
temperature 245, 246
Mineral Commissioner, reports of 260
water 75
Misery Bay 187
Moench and Sons Company well 172
Mohawk mine 260
Monroe beds 147, 219, 222, 228, 273
analyses by Rominger 157
or Salina 230
Mt. Clemens 211
Mudge, E. H. 51
Muskegon county 104, 212, 232, 251

Neebish Island 227
Nellist, J. F. 77
Neodevonian (Antrim) shale 220, 221, 222, 232
New Baltimore well 221, 241
Newberry J. S. 51
New Buffalo 212
Niagara 71, 145, 220, 223
Guelph 228, 230
limestones 145
analysis of, by Rominger 156
Nickel 131, 133, 243
Niles 213, 253
Nipissing Great Lakes 54
Norwood village 199, 208

Ogemaw 9, 15
Oil 6, 73, 128, 212, 224, 226, 236, 237, 271, 275
analyses of 229
deposits 272
and gas possibilities 71, 74, 211
springs 269, 272, 273
source of 270
Olivet 253
Omer 20, 24, 153
Osborn cave 146
Oscoda wells 69
Owosso 211

Papst, R., well of 281
Parma 225
Partridge Point 195
Pearls 136
Peat 73, 99, 127, 264
Peat and celery 117
Peridotite 51
Petoskey, well 197, 199
Jarman's quarry 204
limestone 210
Petroleum 204, 211
Petrolia 269, 273

Page.
Pewamo channel 51
Phosphorus 131
Pine River 22, 44, 207, 208
stumps 97
Plant societies 28, 79–105
of low lands 98, 100, 101
of Muskegon county 107
Pleistocene 219, 220, 221, 222, 223, 224, 228, 232, 234, 236
See also glacial, ice and surface deposits.
Portage redstone 134
Port Huron 211, 221, 249, 270, 275, 280
Portland Cement 136, 137
Potsdam 227

Rapid River 229
Rate of deposition of strata 243
Raw material 136
Read, M. E. 51
Reef off Harrisville 65
Coral 176, 202
Richardson, G. B., analyses by 142
Richmondville sandstone 279
Richter, Wm. 252
Rifle River 20, 21, 22
Riga 219
River Rouge 218, 241
Road metal 117
Rochester shale 228, 231
Rominger 144, 156, 164
Rose's quarry 204
Ruschhaupt, Fr. 229
Russell, Prof. I. C. 107, 108
Ryerson's well 234

Saganing creek 22
Saginaw 211, 223
Coal Co. 6
county 5, 124
Valley brine, analysis of 242
Salina 147, 156
Salt 74, 135, 241, 273
Salts 66
Sand for glass manufacture 134
Sand 232
Sands, lake 105, 106
for sanding paint 134
Sandstone, Lake Superior 50
Marshall 64
Portage redstone 134
Marquette brownstone 134
Sarnia 273, 274
Schneider, E. J. 182
Shale—bituminous 20
black 185
Shaw well 281
Sherzer, W. H. 51, 108, 257
Shingle shore 291
Silurian 236
Sibley Quarry Co. 149
South, C. D. 257
Smyth, H. L. 142

Page.
Snow, effect of 246, 247
Soda 135
Soils 28, 29, 55, 115, 116
plants, effect on 102
Soil horizon 291
temperature 245, 251
of Lapeer county 115
Sources of soil 270
South Bay City 224
Spalding, Prof. J. V 107
Spencer, J. W 51, 53
Standish 24, 26
St. Clair 222, 241, 249
River 69
St. Ignace 227, 248
St. Joseph's Island 227
Stevens, H. J 260
Stock, G. B., wells of 276
Stony Point 195
Stratification of clay 284
Stroh's brewery well, Detroit 217
Stromatopora 201
Stronach 237
Stontium 148
Sugar factories 257
Swamps 45, 99, 100, 116
Sylvania sandstone 216, 219, 220, 223

Tawas City 25
River 22
Taylor, F. B 38, 52, 53, 108
Tecumseh Salt Co 218
Temperature 249
and precipitation at Harrisville 40
of air 245, 247, 251
of artesian wells 248
of mines 245
of soil 245, 251
Thunder Bay Island 185
series 175, 192
Tittabawassee township 252
Topographic survey 261, 263
T. 16 N., R. 16 E 278
T. 6 N., R. 17 ..... 276, 277
T. 9 N., R. 17 E 285, 286
T. 9 N., R. 13 E 279
T. 7 N., R. 17 E 280, 281
T. 10 N., R. 17 E 283
T. 19 N., R. 4 E 18, 19, 21
T. 19 N., R. 5 E 14, 19
T. 20 N., R. 3 E 21
T. 20 N., R. 7 E 12, 13, 27
T. 21 N., R. 3 E 21
T. 21 N., 5 E 16
T. 21 N., R. 7 E 27
T. 22 N., R. 5 E 16, 23
T. 22 N., R. 6 E 16
T. 22 N., R. 7 E 27
T. 23 N., R. 5 E 43
T. 24 N., R. 6 E 64
T. 24 N., R. 16 W 64

Page.
T. 25 N., R. 5 E. 50, 56, 73
T. 25 N., R. 6 E. 50, 56
T. 25 N., R. 7 E. 42, 43, 47, 50, 56
T. 25 N., R. 8 E. 47, 56, 63, 73
T. 25 N., R. 9 E. 43, 47, 56
T. 26 N., R. 5 and 6 ..... 43, 64
T. 26, R. 6 E. 43, 56
T. 26, R. 7 E. 43, 56, 63
T. 26 N., R. 8 E. 47, 56, 59, 72
T. 26 N., R. 9 E. 43, 56
T. 27 N., R. 5 E. 43, 50, 57
T. 27, Rs 5 and 6 43
T. 27 N., R. 6 E. 41, 43, 50, 57, 63
T. 27 N., R. 7 E. 41, 43, 57
T. 27 N., R. 8 E. 41, 43, 48, 57, 63
T. 27 N., R. 9 E. 41, 43, 57
T. 28 N., R. 5 E. 43, 50, 57
T. 28 N., R. 6 E. 58
T. 28 N., R. 7 E. 58
T. 28 N., R. 8 E. 43, 50
T. 28 N., R. 9 E. 41, 43, 50, 58
T. 31 N., R. 7 E. 193
T. 32 N., R. 8 E., Sec. 25 186
T. 42 N., R. 31 W. 144
T. 44 N., R. 7, Sec. 16 146
T. 44 N., R. 32 W. 144
T. 48 N., R. 28 W. 143, 144
Traverse (Hamilton) group 66, 70, 163, 196, 216, 219, 220, 221, 222, 223, 272
analyses by Rominger 157
thickness of 210
limestone 184
Trenton formation 145, 217, 219, 227, 229
analysis by Rominger 156
Turner 24, 25
Tuscola county 5
Twining 24

Ubly 52
Unionidae 138
United States Geological Survey 108, 142, 260, 262
Upham, Warren 52
Upper Marshall or Napoleon 225
Upper Peninsula 254
Utica 229

Valley Center well 279
Van Hise, C. R. 254, 262
Van Etten Creek 44

Wadham's station 278
Walker, B. 137
Wallaceburg 223
Washtenaw county 107
Waste, rate of 287
Water 75
level, variation in 123
power 63, 123, 126, 260
supply 21
Wells of Alpena county 58, 60
Muskegon county 106
Well's boring at Port Huron 249, 280
West Branch 25